Eng. Lib.

COMPRESSED AIR MAGAZINE

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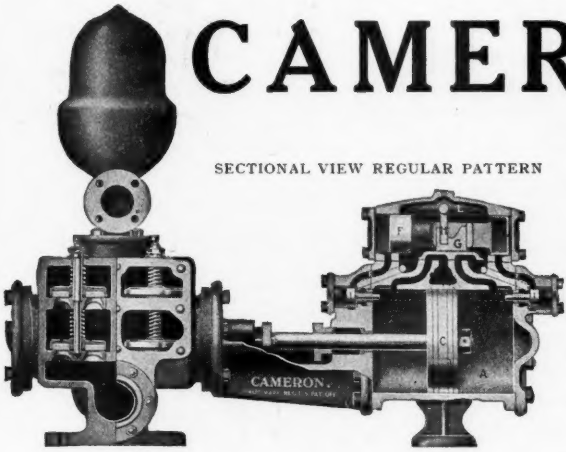

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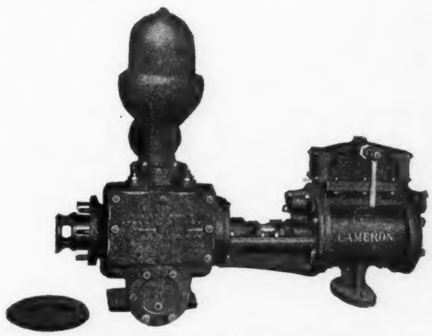

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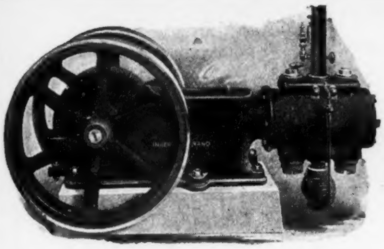

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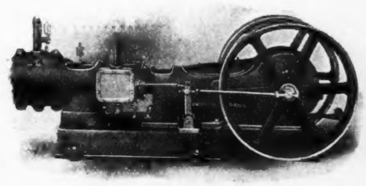

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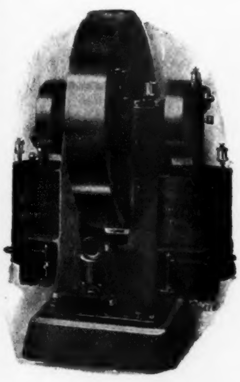
Steel parts are oil treated and annealed, adding at least 25 per cent. to their strength; cast steel is largely used where others use cast iron; cast iron is of a special quality; bearings are unusually large; splash lubrication is used on horizontal types, sight-feed oilers on vertical models.



"Imperial XI" Power Driven

Straight line types include the "NF-1" steam driven, and the "NE-1" power driven. Vertical types include the "Imperial XI", the "Junior" and the "Baby".

Capacities range from 6 to 600 cu. ft. per minute, for all pressures up to 100 lbs.

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COMPRESSED AIR MAGAZINE

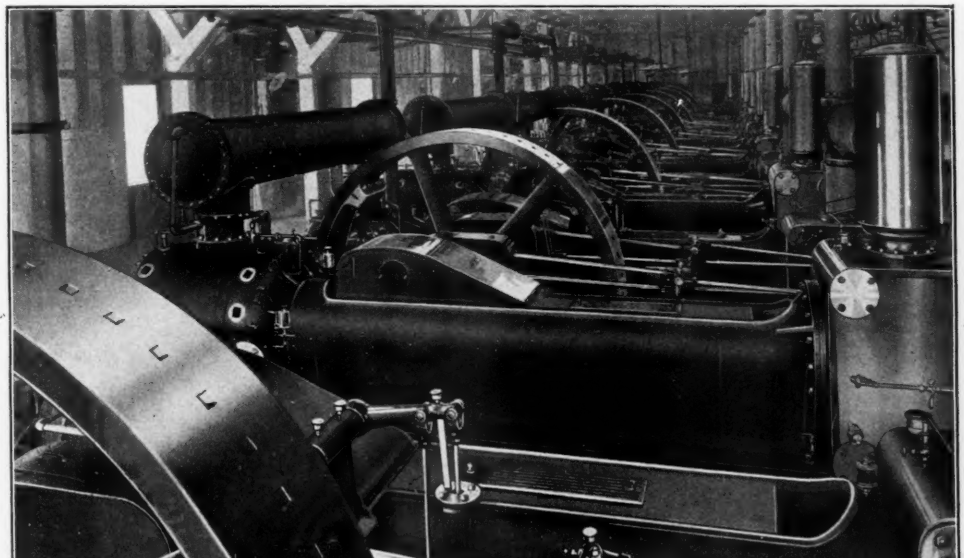
EVERYTHING PNEUMATIC.

Vol. XV FEBRUARY, 1910 No. 2

THE RONDOUT TUNNEL RECORD

The following we abstract, with slight interpolations, from a recent paper in the *Engineering Record* by Mr. John P. Hogan, Assistant Engineer, Board of Water Supply, New York City, whose position gives him unequalled facilities for full and accurate statement.

The tunnel near High Falls, N. Y., is part of Catskill Aqueduct, which will carry water from Ashokan Reservoir to New York City. It is 23,608 ft. long, 4½ miles, and is designed for a finished waterway of 14½ ft diameter and an average thickness of lining of 17 in., making the required excavation 17 ft. 4 in. in diameter. As the tunnel in service will be subjected to great internal pressure a rock cover of at least 200 ft. was considered necessary, and the line is therefore from 100 to 250 ft. below sea level and is reached from eight shafts, varying in depth from 347 to 710 ft. Three of these shafts are circular, approximately of the same size as the tunnel, and will be used permanently in the operation of the aqueduct,, and five are rectangular shafts, 10x22 ft. outside of timbers, sunk to expedite construction and to be sealed and refilled at the close of the work. An unusually varied assortment of sedimentary rocks is encountered, varying from a comparatively soft shale to a hard quartz Conglomerate.

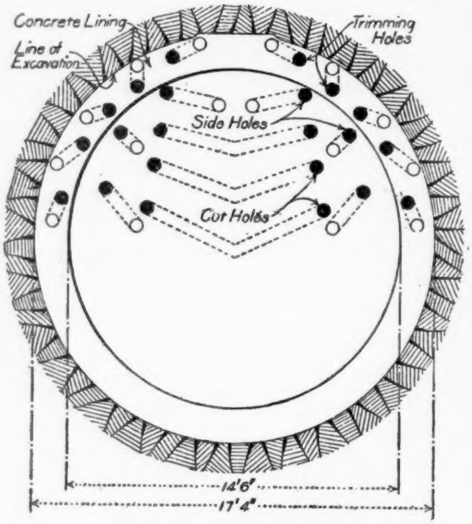


AIR COMPRESSORS AT HIGH FALLS DRIVING RONDOUT TUNNELS.

The contract for this tunnel was awarded to the T. A. Gillespie Company of New York on June 12, 1908, and the progress has been exceptionally rapid. What is said to be the largest high pressure compressed air plant in the world, comprising ten Ingersoll-Rand Imperial, compound steam and two-stage air compressors and supplying 23,000 cu. ft. of free air per minute at a pressure of 100 lb., was in operation five months after the contract was let. This plant was described in COMPRESSED AIR MAGAZINE, June, 1909, and a photo since made of the interior of the compressor house is shown on the preceding page. The average monthly progress in seven of the shafts was about 70 ft. per shaft, and the record for a month was 138 ft., all timbered.

Heading 7S, in which a record advance of 488½ ft. was made in November, which in a way makes the opportunity for the present writing, is in the Hudson River shale, a hard slaty material with distinct stratification, the dip being about 65 deg. and the strike at an angle of about 67 deg. with the axis of the tunnel. The best-known exposures of this rock are in the cuts of the West Shore Railroad opposite Poughkeepsie and thence north for about 20 miles. The position of the strata is favorable to good progress; the rock is firm, requiring no timbering, drills well, and breaks to good lines. The tunnel is driven from a construction shaft 514 ft. deep and the heading was 1400 ft. in at the beginning of the month. The inflow of water is slight.

The method used is the typical American top heading and bench plan, approximately half of the tunnel being taken out in each operation, and enough loose muck left in the bottom to permit of two tracks just back of the bench. The bench excavation is kept about 50 ft. back of the heading to allow room for the heading muckers and is excavated in one shift. Four 3¼-in. Ingersoll-Rand drills mounted on two vertical columns are used in the heading and two drills of the same type mounted on tripods for the bench. As both excavation and concrete are paid to fixed lines, great care is taken in placing the holes, and the sections are uniformly good with small excess breakage. The number and spacing of the drill holes is shown in the accompanying sketch. The average number of holes in a heading is 22, divided into six cut holes, six side or relief holes and 10 rim or trimming holes. The cut holes are from 10 to 12 ft. deep and the remaining holes from 8 to 10 ft., depending on the amount of ground to be broken. The bench rounds are 4 ft. apart and average four holes each. Two rounds of the bench are shot with the cut, and the side and trimming holes are then loaded and shot successively, making three shots for a complete advance in which 175 to 200 lb. of 60 per cent. dynamite is used.



PLAN OF HEADING HOLES.

The contract is on a strict eight-hour basis, two shifts of drillers and three shifts of muckers being employed. The drillers work from 8.00 to 4.30, day and night, with half an hour for lunch, and the muckers from 8.00 a. m. to 4.00 p. m., 4.00 p. m. to 12.00 p. m. and 12.00 p. m. to 8.00 a. m., with 15 minutes for lunch. The drillers are expected to set up drill, load and shoot a round within the eight hours, and as no overtime is allowed, failure to accomplish this results in loss of a shot. Between 4.30 to 8.00 the muckers are expected to clean out the heading to permit setting up promptly. The drilling force consists of a heading foreman, six drillers, six helpers and a nipper.

While the rock is easily drilled the tunnel is of such a size and shape that the mucking limits the possible progress. The required excavation is 8.7 cu. yd. of solid rock per linear foot, but the cross-section does not permit the use of a steam shovel or other mechanical device for loading the muck, so hand methods

are used entirely. One 30-in. gage track runs from the bottom of the shaft to the bench, where two tracks are maintained for a short distance. Switches are installed at intervals of about 1000 ft. to permit passage of cars. The heading muck is loaded in wheel barrows and wheeled out on an elevated running board supported on horizontal struts whence it is dumped directly into the cars. The cars are handled in groups of two, one of which is loaded from the heading and the other directly from the bench to encourage competition. Steel side-dump Koppel cars are used having a maximum capacity of 40 cu. ft. of loose rock and these cars are hauled by mules both below and above ground. The mucking force for the heading consists of one foreman, eight shovelers in heading, four wheel barrow men, six shovelers on bench, two mules and drivers and a water boy.

The shaft is equipped with a pair of balanced cages each 68x94 in. operated by an 11x14-in. Lambert hoisting engine. The normal hoisting speed is about 400 ft. per minute and the safety devices include landing dogs, automatic gates, safety dogs on the cages and an automatic cut-off on the engine for the prevention of overwinding. Ventilation is supplied through a 14-in. pipe by an electrically operated No. 6 Sturtevant blower. The force employed at the shaft consists of one day and one night superintendent and one master mechanic for both headings, one signal man at top and one at bottom and a hoist runner, blacksmith and helper for each of the three shifts. In addition there is a top man, a mule and driver, and a dumpman for each heading and a varying number of electricians, pipe fitters, machinists, etc.

All of these men, with the exception of the muckers, receive, as a bonus, 1 per cent. of their salary for every 5 ft. made during the month in excess of 225 ft. At the time of the inauguration of the bonus system the muckers received a flat raise from $1.60 to $1.75 per day.

In comparing this progress with other American and European records attention is called to the fact that the tunnel is driven from a deep shaft, to the limitations imposed by the size and shape of the tunnel and the eight-hour law, and to the fact that economy has not been sacrificed to speed. During the month one day was lost on account of necessary repairs and alterations at the shaft. The tunnel is just of the awkward size where the amount of muck represents a serious problem and no satisfactory mechanical device can be used. The circular shaft does not lend itself to the use of the horizontal bar of the European drill carriages on account of the difficulty of drilling the trimming or rim holes.

It is significant that the recent marked advance in American tunnel progress has spread from the Rocky Mountain territory to the eastern part of the country, both to Chicago and New York. It is felt that this is in a large measure due to an improvement in organization and system and to the gradual training in the different localities of skilled corps of tunnel workers who make a specialty of this class of work.

The Rondout Pressure Tunnel is being constructed by contract for the City of New York under the direction of the Board of Water Supply; Messrs. John A. Bensel, president, Charles M. Chadwick and Charles A. Shaw. Mr. J. Waldo Smith is chief engineer; Mr. Robert Ridgway, department engineer, Northern Aqueduct Department; Mr. Lazarus White, division engineer, Esopus Division, in which the Rondout tunnel is located, and Mr. Bertrand H. Wait, section engineer, Section No. 6. The T. A. Gillespie Company are the contractors. Mr. Robert Swan, vice-president and general manager, Mr. R. J. Gillespie, general superintendent, and Mr. John Dillon, superintendent of heading 7 S, in which the record was made.

AN INDEPENDENT DIVING OUTFIT

A new diving apparatus invented by a German engineer, was tried recently in the River Trave, at Lubeck. The apparatus renders the diver totally independent of any attendant vessel. In a small steel cylinder he carries a quantity of oxygen and a long air-pipe is not required. It is stated that the diver, with the new apparatus, can work under water for several hours, and be perfectly free in his movements, before coming again to the surface. The trial is reported to have been a perfect success; the diver descended into the River Trave, remained under water a long time, and came up again quite fresh and vigorous. By the aid of ingeniously constructed valves, oxygen is paid out from the cylinder at a rate to suit the requirement of the diver's lungs.

ANIMALS USED IN GAS TESTS

At a recent meeting of the South Staffordshire and Warwickshire Institute of Mining Engineers an important lecture was delivered jointly by Drs. I. S. Haldane and C. Gordon Douglas. In the course of the lecture many experiments were made with birds, mice and other animals and in the beginning an explanation justifying their use was presented.

Mining engineers have no need of a test for a gas which shows its presence, as many gases do, by causing pain or discomfort; and in common with other educated men they dislike all cruelty to animals. It is just because carbon monoxide has the special peculiarity of causing no pain or sensible discomfort in its action that a special test for it is required. For the same reason the use of small animals in detecting carbon monoxide does not come under the Vivisection Act.

The principle of the test is as follows:—In small warm-blooded animals, the rate at which chemical changes occur in a given body-weight is enormously greater than in large animals. Thus a mouse weighing about half an ounce consumes about fifteen times as much oxygen as half an ounce of the human body would consume in the same time. A reason for this difference is evident enough. With bodies of the same shape and composition, but different sizes, the surface increases as the square of any corresponding dimension, but the mass as the cube. The larger an animal is, therefore, the less surface will it have for a given mass, and the less rapidly will a given mass of it lose heat to the environment; or the less heat, and consequently the less oxygen, will a given mass of it require in order to maintain the normal body temperature. Not only are the chemical changes in the small animal far more rapid, but the rates of respiration, circulation, etc., are correspondingly increased. It is difficult to count by the eye the rate of breathing in a mouse, and quite impossible to count its pulse rate. By a photographic method of recording the electrical changes which accompany the heart beat, Miss F. Buchanan, of Oxford, has recently shown that the pulse rate in mice and small birds is from 700 to 1,000 per minute.

It follows that the small animal will absorb any poisonous gas far more quickly than a man will, and will therefore show symptoms of poisoning far sooner. It can, in fact, be employed to show what will ultimately happen to a man if he remains in the poisonous air. This, and this alone, is the principle of the test. The small animal is not, in the long run, more sensitive than a man to a given percentage of carbon monoxide. Indeed, the opposite is almost certainly the case; for the central nervous system is in many ways more liable to harm than that of any lower animal, and an animal seems to recover much more readily and rapidly from the effects of the gas than a man does. The writers have never observed in animals any of the after-effects which so commonly follow partial poisoning by carbon monoxide in man.

As is now well known, carbon monoxide exercises its poisonous action by combining, to the exclusion of oxygen, with hæmoglobin, the red colouring matter of the blood, and thus preventing the hæmoglobin from exercising its normal function of conveying oxygen from the lungs to the tissues of the body. With the comparatively small percentages of carbon monoxide met with in mines, it takes a considerable time for enough of the gas to be absorbed into the blood of a man to produce appreciable symptoms. Even with a poisonous proportion of carbon monoxide in the air it may take half an hour to produce serious symptoms, while a mouse or small bird is correspondingly affected in two minutes. With smaller, but still serious, proportions of the gas it may take as much as two or three hours for symptoms to be produced in a man. Thus with 0.1 per cent. of carbon monoxide in the air the writers have found that it took about two hours before giddiness, etc., began to appear in one of them during rest. Periodic analyses of the blood showed that absorption was proceeding steadily, and that another half hour would have sufficed to produce practical disablement. A mouse is similarly affected within ten minutes.

With less than about 0.02 per cent. of carbon monoxide in the air, noticeable symptoms are never produced, since absorption ceases when the blood becomes saturated to a comparatively slight extent, although even this would take several hours during rest. Owing to the fact that a state of equilibrium tends to establish itself between the carbon monoxide in the blood and that in the air breathed, and that this equilibrium may be established at various levels, corresponding (if any symptoms at all

are produced) to various degrees of disablement, there is a very wide range between percentages of carbon monoxide which will cause sensible inconvenience and those which will cause death. Men may be disabled for hours or days by carbon monoxide in mines, and yet finally recover. The writers do not know accurately what percentage of the gas is required to cause death in a man within an hour or two, but usually about 0.5 per cent. is needed in an animal, although as little as 0.2 per cent. may be fatal. Analyses made by the writers, of the blood of men who have been killed at various colliery explosions show that the hæmoglobin is usually about 80 per cent. saturated with carbon monoxide when death occurs. On the other hand, it is known from experiments on man published by one of the writers in the *Journal of Physiology*, that practical disablement occurs when the blood is about 50 per cent. saturated with carbon monoxide.

The lecturers then proceeded to show the effects of carbon-monoxide on small animals. A canary in a cage, and several mice, were placed in a large bell-jar of about 15 gallons capacity. By means of soft wax the bell-jar was fixed airtight on a painted wooden slab, through which passed a tube through which a man could breathe the air of the bell-jar, and the axle of a small fan for mixing the air. For the purpose of comparison, other animals were placed in a second bell-jar containing pure air. From a measuring cylinder containing pure carbon-monoxide sufficient of the gas was then driven by a stream of water into the first bell-jar to raise the proportion of carbon-monoxide to about 0.1 per cent., the whole of the air being at the same time thoroughly mixed by means of the fan. It was seen that in the course of about eight or ten minutes all the animals became sluggish in their movements, and less lively. The canary seemed rather uncertain on its perch, and the mice remained quiet, or frequently stopped, as if they became faint after a slight exertion. On doubling the percentage, these symptoms became exaggerated, and the legs of the animals tended to sprawl. On removing the bell-jar, all the animals became normal again after two or three minutes.

The bell-jar was now replaced, and about 0.6 per cent. of carbon-monoxide was driven in, the air being mixed by means of the fan, as before. At the same time, one of the writers began to breathe the air of the bell-jar through the breathing tube. In about two minutes all the animals became helpless, and rapidly became comatose or died, while the person breathing the mixture was quite unaffected, even after ten minutes. A drop of his blood was then taken from a finger and diluted in a test-tube with water to the same depth of colour as a diluted sample of normal blood previously prepared. It was seen that the sample taken after breathing the carbon monoxide had a distinct pink tinge, but was not nearly so pink as a sample of the normal blood after it was saturated with carbon-monoxide by shaking it up with coal gas. The degree of pinkness indicated that the sample from the finger was about one-fourth saturated with carbon-monoxide, this degree of pinkness being insufficient to cause appreciable symptoms.

If a mouse is used for testing, the animal should be in a cage large enough for it to creep about; otherwise, there will be difficulty in judging the effect of carbon monoxide upon it. For the same reason, a bird should have a perch in its cage. Birds are more easily killed by carbon monoxide than mice, owing, probably, to the fact that they are apt to struggle if they lose their balance, and that any sudden exertion is dangerous. In one sense, therefore, the bird is a better indicator of carbon monoxide than a mouse. But if the animal dies, it ceases to be of use as an indicator, just as a safety lamp becomes useless if it is extinguished. From this point of view, the mouse is superior. A miner needs to know, not only whether he is in dangerous air, but whether he has got back to safe air. If animals larger than mice or small birds are used, it must be remembered that they take a correspondingly longer time to react to the carbon monoxide. A rat or pigeon will take about twice as long as a mouse, a rabbit twice as long as a rat, and so on up to a horse, which probably takes twice as long as a man. The rate of recovery from carbon-monoxide poisoning is correspondingly slower in the larger animals.

A man who is moving about breathes much more air than a man at rest, but the rate at which he absorbs carbon monoxide does not increase in the same proportion. The carbon monoxide may, however, be absorbed about twice as fast as during rest. Even, however, if this is the case, it will take seven or eight times as long for the man as for the mouse to be affected.

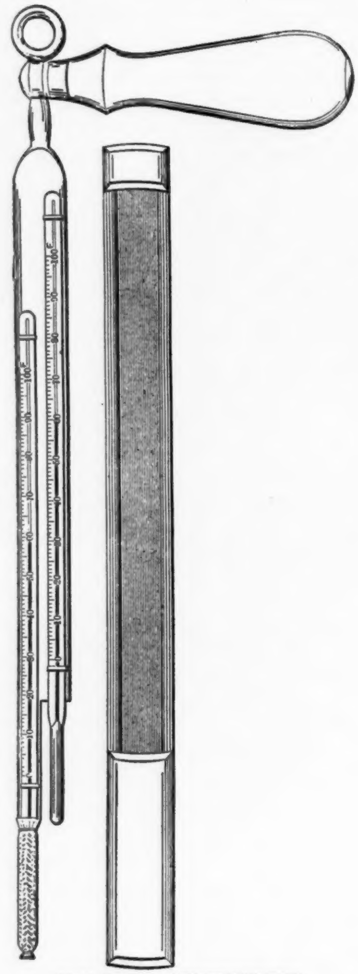
DEALING WITH ATMOSPHERIC HUMIDITY

Our atmosphere consists principally of a mechanical mixture of nitrogen, oxygen and aqueous vapors. The per cent. of the last-named component varies almost constantly under natural conditions, and as a matter of fact is kept from varying under artificial conditions only with great difficulty. Where abnormal humidity exists, as in cold-storage warehouses, where the cooling of partially saturated incoming air often produces a condition of saturation, and where the per cent. of saturation may also be increased by the moisture cooled from the products stored, a deliquescent moisture-absorbing salt, such as calcium chloride, may be employed to reduce the humidity. The salt is usually exposed to the air on shallow trays provided with drip pipes which may be arranged to convey the saturated calcium-chloride brine away to a storage tank to await reclaiming, or the brine may be employed as a deporting agent on the ammonia or brine pipes over which it may be arranged to drip slowly as formed.

The only exact method of regulating the humidity of air is artificially to cool it to such a point that the amount of moisture that it will still retain at that temperature, usually after precipitating a large per cent. of its initial complement, will be the required amount when the temperature is allowed to rise to the required point. This general process is employed most extensively in connection with the dehumidifying of air used in blast-furnace work.

The humidity of the atmosphere may be determined by one of two methods: First, by cooling the air until the point of saturation is reached, in which case the per cent. of humidity for any other temperature can be readily determined from well known tables or, second, by observing the drop in temperature produced by the evaporation of a film of water at the original temperature.

Apparatus for determining humidities by the former method are known as "dew point" instruments and by the latter method as "psychrometric" apparatus, more commonly called hygrometers. These instruments are of many forms, but the two most common types are the stationary wet- and dry-bulb thermometer of which the most practical seems to be Lloyd's Hygrodeik and a sling wet- and dry-bulb thermom-apparatus known as the "sling psychrometer." This instrument is employed by the United States Weather Bureau and is the most popular humidity-determining instrument employed in cold-storage work, especially when low temperatures are to be dealt with.



THE SLING PSYCHROMETER.

The instrument consists of two thermometers so mounted on a common scale that one bulb extends below the other. This bulb is covered with a thin layer of muslin which is kept saturated when the instrument is inserted in its case, which is provided with a cup kept full of water. This cup is only sufficiently deep to allow the lower muslin-covered bulb to enter, the upper bare bulb being always dry.

In taking observations the instrument is removed from its case and swung rapidly around on its pivoted handle. Contact with the air

produces a rapid evaporation of the moisture on the wet bulb, which evaporation causes that thermometer to register a lower temperature than that of the dry-bulb thermometer. The difference in the readings of the two thermometers constitutes a basis for arriving at the per cent. of humidity present in the air tested.—*Power and the Engineer.*

COMPRESSED AIR REGULATIONS IN FRANCE

A decree of the French republic imposes upon all persons in charge of work in compressed air a number of definite obligations looking to the safety of the men employed. The following, abstracted from *Annales des Ponts et Chaussees,* gives the principal requirements:

A physician shall be employed and shall have medical supervision of the men, and before a man may enter the air he must show this physician's certificate. The certificate must be renewed 15 days after first employment, and thereafter once a month. Provision is made for examining men who have special troubles with nose, throat or ears. An individual record mentioning accidents or cases of illness must be kept of each member of the force. Intoxicating liquors must be excluded, and any workman intoxicated must be kept away from the work for 24 hours.

The time for compression shall be at least 4 min., when increasing from 1 to 2 atmosphers, total effective pressure, and at least 5 min. for each additional atmosphere.

The time for decompression shall be not less than 20 min. for each atmosphere above 3, absolute, 15 min. for pressures between 2 and 3, and 10 min. from 2 down to zero gage pressure.

If the pressure has not exceeded 2 atmospheres, 15 lb. gage, the time to decompress down to zero may be reduced to 5 min.

A caisson may not be lowered by suddenly reducing the pressure without first taking out the men.

Every lock must have a pressure gage, and if the gage pressure exceeds one atmosphere a recording gage is required.

The working chamber must be high enough for men to stand upright in it, and never less than 5 ft. 11 in.

At least 40 cu. m. (1,412 cu. ft.) must be supplied per hour per man, and carbonic acid must not exceed 1 in 1,000. If the air supply stops the men must be ordered out after 10 min. at the most.

Blasting is not permitted in the working chamber until the men have left it, and they must not reenter until the air has become normal, temporary refuge in shaft or lock being permitted.

The volume of air in the lock shall be at least 600 cu. decimeters (about 21 cu. ft.) per man. The renewal of air in locks during periods of decompression exceeding 10 min. shall be assured by opening simultaneously inlet and outlet valves thus allowing a flow of air through the lock. In summer locks exposed to the sun shall be protected by a tent or matting kept wet. When the work requires more than 20 men in the air at one time, communication between the working chamber and the surface shall be provided for by a telephone.

Special precautions should be taken to prevent, in case of an attack of giddiness, a man's falling at the entrance to the lock. Provision also is made for controlling entrance to and exit from the air from both the high and low pressure sides. The shaft should be accessible at all times and ladders maintained in it. Equipment must be provided for taking out workmen if they are unable to climb the ladders. The air lock, shafts, and working chamber shall be illuminated by electric lights.

Each air pipe shall be fitted with a check valve, which will close when the pressure in the working chamber exceeds that in the pipe. Automatic regulation of the pressure of air sent into the caisson should be provided for. An outfit for affording aid to the injured shall be kept on hand; it shall include a tank of oxygen under pressure, or other means of supplying quickly and easily a quantity of pure oxygen.

When work is carried on under an effective pressure of more than 17 pounds gage, a house, where the men coming from the air may rest, shall be built near the entrance to the work; its dimensions shall depend upon the number of men working simultaneously in the compressed air. It shall be suitably ventilated, heated, and fitted with wash stands, soap and towels for each workman, dressing room, and couches. When the pressure in the working chamber exceeds 30 pounds, gage, there must be installed a hospital-lock, containing a bed, and large enough to receive two attendants.

Compressed air workers must be at least 18 years old.

TWO-STAGE AIR FROM A SINGLE-STAGE COMPRESSOR

Mr. George L. Fales gives in *Power and the Engineer,* from which the accompanying cuts are taken, an interesting account of the taking advantage of circumstances in connection with a standard air compressor by which its output was considerably increased, its working temperatures were considerably lowered and the cost of compression per unit of volume also reduced, while the cost involved in the arrangement was not large. The narrative treats in fact of the converting of a single-stage compressor into a two-stage machine by using a portion of the air from a compressor in low pressure service as first-stage air in the regular compressor.

pressor was again in service. At the pressure and speed, 100 revolutions per minute, at which it was necessary to operate to get the required pressure with the Ingersoll compressor, the air was so hot when delivered that occasionally the oil in the receiver would ignite and burn, and the packing on the air-cylinder heads would char and blow out.

This compressor happens to be located between two Nordberg Corliss cross-compound blowing engines, 15 and 30 and 40 by 42 inches, compressing air to 12 pounds for blowing converters; each of these engines has a large air receiver connected to the outlet flanges over each air cylinder, and the two receivers are connected by two 12-inch lines of pipe running horizontally between the ends.

The 12-inch line pipe, shown in Fig. 3, was used as a source of supply of first-stage air. The pipe was cut on the bottom side and a

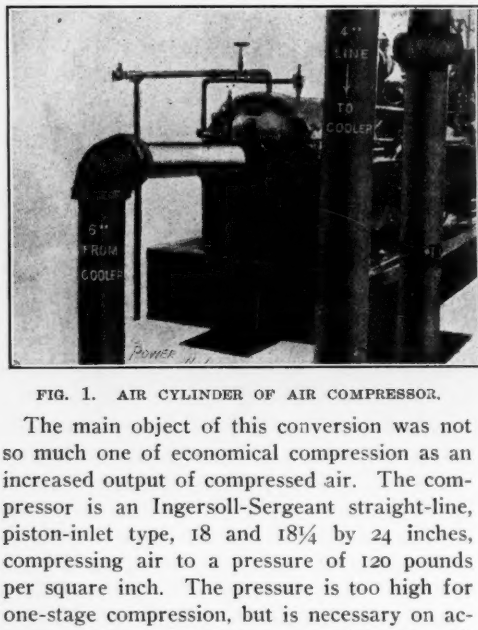


FIG. 1. AIR CYLINDER OF AIR COMPRESSOR.

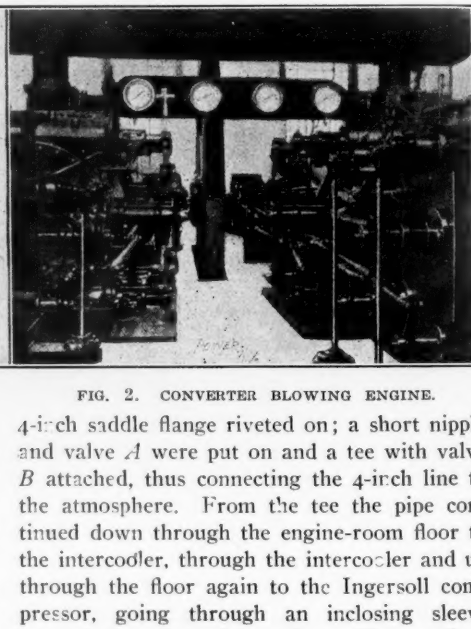


FIG. 2. CONVERTER BLOWING ENGINE.

The main object of this conversion was not so much one of economical compression as an increased output of compressed air. The compressor is an Ingersoll-Sergeant straight-line, piston-inlet type, 18 and 18¼ by 24 inches, compressing air to a pressure of 120 pounds per square inch. The pressure is too high for one-stage compression, but is necessary on account of using the air to move sulphuric acid.

With normal consumption of air this compressor and a smaller two-stage machine were just about enabled to supply the required amount of air at very near their maximum speed, the supply going not only to pump acid but also to tamp converters, for boiler-shop work, etc. This was 24-hour duty, and when repairs were needed on either compressor the supply of air was always short until the com-

4-inch saddle flange riveted on; a short nipple and valve *A* were put on and a tee with valve *B* attached, thus connecting the 4-inch line to the atmosphere. From the tee the pipe continued down through the engine-room floor to the intercooler, through the intercooler and up through the floor again to the Ingersoll compressor, going through an inclosing sleeve around the piston-inlet pipe. The cooling-water line for the air compressor jacket was fitted with valves *F*, *G* and *H*, and the water was bypassed as shown, going into the jacket after it had first passed through the intercooler. The drip line and valve *I* removed the oil and water that accumulated in the bottom of the intercooler. To run single-stage, the valve *A* is closed and valve *B* is opened, using air at atmospheric pressure through the intercooler.

The intercooler, shown in section in Fig. 4, was a piece of 12-inch pipe, 10 feet long, with flanges attached at each end. The tube sheets were two blank flanges 1 inch thick, drilled and recessed as shown in the drawing. On the inside of one of the tube sheets a baffle plate was riveted in the center, extending the whole width of the pipe and three-quarters of the length, to make the entering air traverse the full length of the tubes. The heads on each end were ¾-inch iron, flanged and dished, and

compressor ends at the floor line in a reducing 6-inch flange which is tapped out for ¾-inch cap screws instead of bolts; from this flange a 6-inch companion flange and a piece of 6-inch pipe extend upward to the 6-inch ell fitted at the end next to the compressor. A stuffing box and gland inclosing sleeve *A* fit into the other end of the ell and allow for any expansion or contraction. When it is necessary to pack the compressor gland, the cap screws on the 6-inch flange at the floor are re-

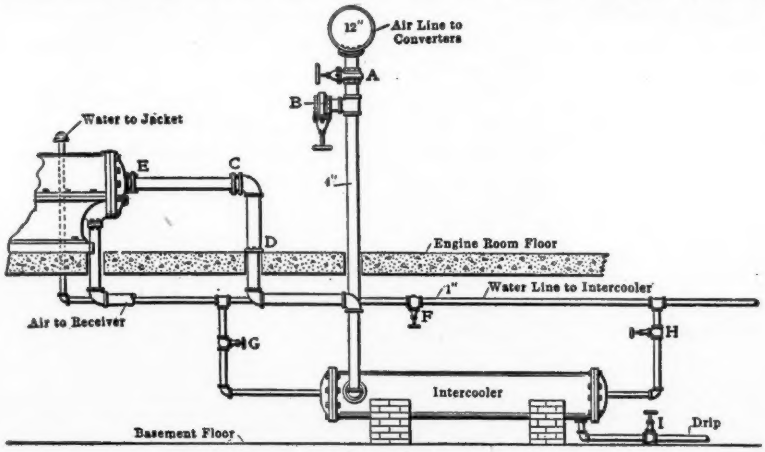


FIG. 3. PIPING TO AIR CYLINDER OF COMPRESSOR

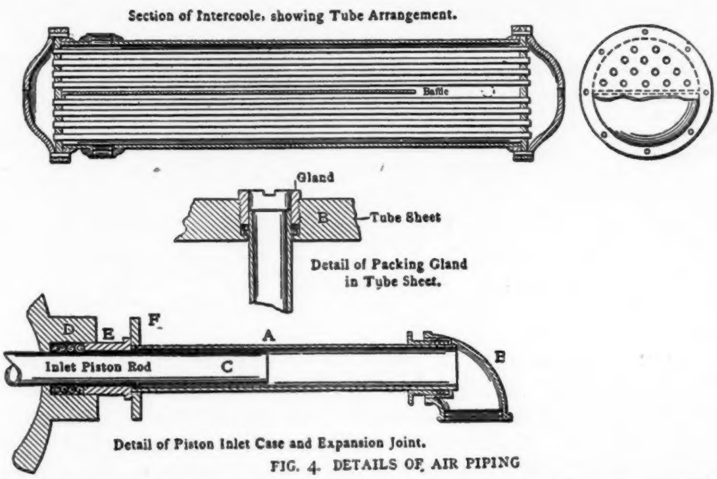


FIG. 4. DETAILS OF AIR PIPING

twenty-eight 1⅛-inch brass tubes were inserted through stuffing boxes. A 4-inch saddle flange on each side of the 12-inch pipe at one end provides entrance and exit for the air, and a 1-inch opening on the bottom at the opposite end acts to drain the intercooler. The 4-inch line going from the intercooler to the

moved, and the sleeve and packing gland, which are all one, are moved out enough to enable packing to be inserted in the stuffing box.

A detail of the sleeve inclosing the piston inlet pipe is shown in the drawing to consist of a piece of 5-inch pipe, turned smooth on the

outside. The original packing gland *E* was cut down as illustrated, leaving a shoulder which sleeve *A* was forced up against and pinned in place. A flange *F*, which fits loosely on the sleeve *A*, was made to fit up against the shoulder on the gland and holds it in place against the packing, being drawn into the stuffing box by the original gland bolts.

The tracings of the indicator diagrams taken from the air cylinder show the comparative increase of volume in delivered air due to the compounding and intercooling. Since running two-stage the smaller two-stage machine has not been in service at all, except when repairs were being made on the Ingersoll compressor, and then it was put on to hold what air it could until the compressor under repairs was again in service. As a consequence there is always a spare compressor, a plentiful supply of air obtained at a medium speed of the compressor, and the delivered air is at a much lower temperature. There has been but one joint put in the air head since the compressor has been running two-stage, which is five or six months; previously it was about twice a week.

LUBRICATION.

Once on each shift of 12 hours a cake of white soap is dissolved in two gallons of water and fed into the air cylinder through an oil cup on the inclosing sleeve of the piston inlet. This keeps the valves, packing rings, etc., so free from the carbon deposits that the compressor never has to be opened to clean up from this cause. The amount of air used from the converter engine is hardly discernible, as the same amount of work is done with the engine as formerly; it takes some seven or eight revolutions of the converter engine per 100 revolutions of the compressor. Figs. 1 and 2 show the Ingersoll-Sergeant compressor as fitted up and also the engine which supplies the first-stage air.

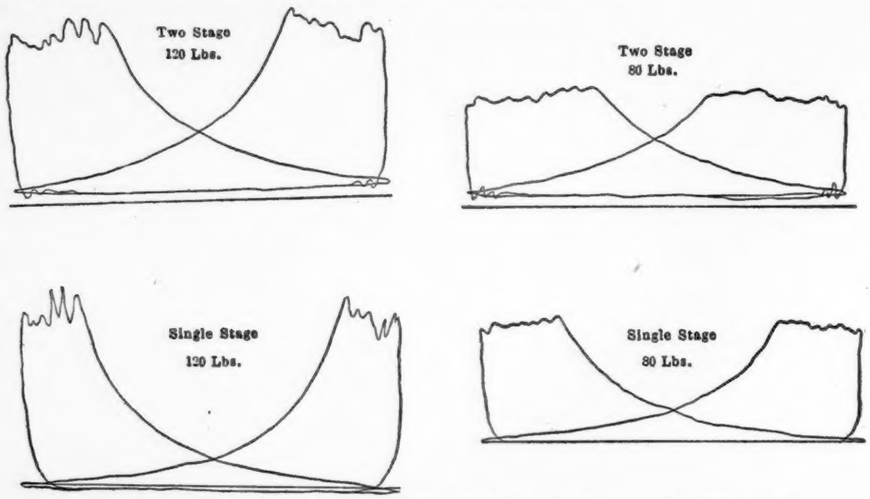


FIG. 5. DIAGRAMS TAKEN ON SINGLE-STAGE AND TWO-STAGE OPERATION

COMPRESSOR DISCHARGE PIPE PULSATIONS

BY SNOWDEN B. REDFIELD.

A great many questions have been asked as to what causes the wide variation in the pressure delivered by an air compressor as shown by the very wavy line of discharge on the indicator card. The only explanation for these irregular lines lies in possible pulsation in the air as it is forced out of the compressing cylinder.

These pulsations are not always alike, or, it should be said are seldom alike, although under given conditions an indicator card from the same compressing cylinder will really show exactly the same wavy lines. Sometimes these pulsations appear to be very much more violent than at other times, and it is found that the higher the speed and the smaller the valve area provided in the compressor, the more amplitude there is to the waves shown on the discharge line of the indicator card. At very slow speeds the vibrations can be almost eliminated with indicator springs of the usual stiffness.

Another way of studying these interesting pulsations in the air pipe leading from an air compressor is to take an indicator diagram from the discharge pipe itself by attaching an indicator to the side of the pipe close to the air cylinder, or wherever it is desired to study the pulsations in the pipe.

It is a curious thing that the figures obtained in this way are always the same as long as the conditions of speed and pressure are unchanged for any particular compressor and position in the discharge pipe, and no matter how violent these vibrations may be, due to high speed, the indicator pencil will go right on over the same lines of the complicated figure produced as long as may be desired. One would think that the pulsations would change parts corresponding to the period of discharge of first one end of the cylinder and then the other, while the low parts are produced during the interval when no air is being forced into the pipe from the compressor; that is, during that part of the compression stroke before the pressure in the cylinder has reached that of the discharge. All of the other diagrams were taken from a compressor pumping natural gas. The various pressures and speeds are marked and it will be seen that for each pressure and each speed there is a distinct diagram for any one cylinder, although, as said, each diagram can be reproduced from a given pipe any number of times as long as the speed of the compressor and the discharge pressure are kept constant.

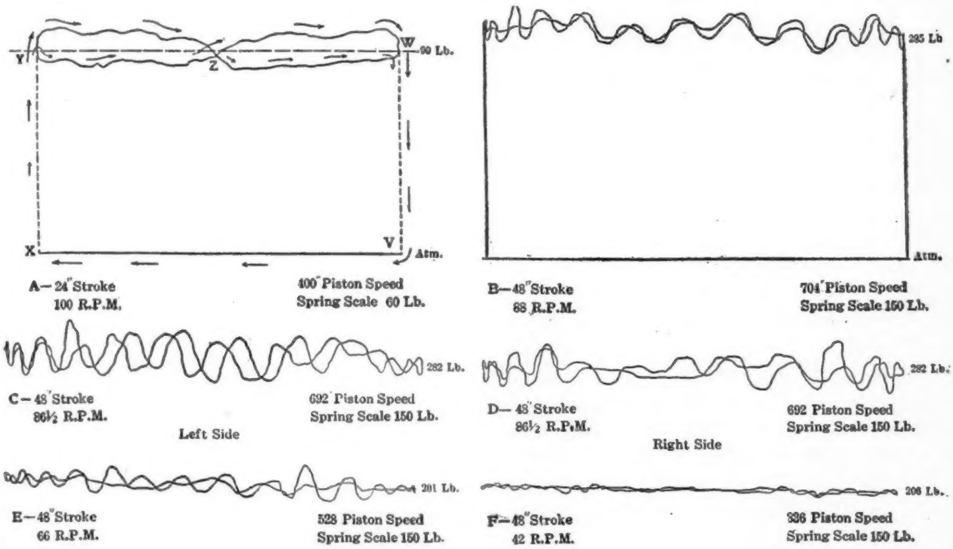


FIG. 1.

from instant to instant when the figure becomes very irregular, and that the diagram produced by continuing to allow the pencil to trace upon the indicator card would finally become nothing but a snarl of lines.

THE DIAGRAMS.

In Fig. 1 there are reproduced several diagrams obtained from compressor discharge pipes. There is shown at *A* an ordinary pipe diagram with moderate speed and moderate pressure. This diagram, as might be predicted, takes the form of an elongated Fig. 8, the high

As the speed decreases the diagram becomes of less and less amplitude, so that at *F*, the lowest speed, it is almost a straight line. At *F* the piston speed is only a little less than at *A*, but it is seen that the diagrams are widely different. This difference is due to two things; first, the scale of the spring in the two cases is entirely different, being 60 pounds per inch at *A* and 150 pounds at *F*. This stiff spring, of course, causes the pulsations to appear of small amplitude, although the actual pressure variations may be as great in the case of *F* as of *A*, but *F* is comparable only with *B*, *C*, *D*

and *E,* taken with a 150-pound spring, and these correctly show the relative effect of speed change under otherwise similar conditions..

THE PRACTICAL USE.

These diagrams may be very curious to look at, but the question naturally arises what are they good for? As a matter of fact, these diagrams may be made to serve a very useful purpose; that is, to determine absolutely what is known as the efficiency of compression of the compressor. The efficiency of compression is the ratio of the theoretical power required to compress a given quantity of air or gas from any one pressure to another, to the actual power required to be developed in the compressing cylinder.

The efficiency of compression depends, for given conditions of pressure and speed, upon the valve area of the compressing cylinder, and consequently is a factor which may be improved by first-class construction. In buying an air compressor, therefore, it is very advisable to find out beforehand what guarantee as to efficiency of compression will be made by the manufacturer. The purchaser almost always asks what volumetric efficiency will be obtained, but the efficiency of compression is usually allowed to remain quietly in the background.

Of course the theoretical power for any given pressure conditions may be figured either by the adiabatic or the isothermal formula, or in fact for any other compression curve. The isothermal is the best that can be hoped for, although never attained with an air compressor, but the adiabatic is very much more nearly equal to what is actually obtained from ordinary compressor practice. It makes no difference which figure is used for comparison as long as it is clearly understood which efficiency (that is, the isothermal or adiabatic) is intended.

THE EFFICIENCY OF COMPRESSION.

As an example of efficiency of compression referred to the adiabatic, we may take the indicator card shown in Fig. 2. This card also was taken from a natural gas compressor and, as is usually the case with natural gas, the intake pressure was very considerably above the atmosphere. The intake pressure to the compressor was 51½ pounds gage, and the gas was then compressed up to 281 pounds, the actual discharge pressure measured in the pipe. Now the theoretical power required to adiabatically compress 100 cubic feet of natural gas from 51½ pounds to 281 pounds at sea level is 49.9 indicated horsepower per 100 cubic feet of gas actually compressed and delivered per minute.

By going over the indicator card shown in Fig. 2 it is found that the mean effective pressure developed in this cylinder is 112½ pounds per square inch. This mean effective pressure corresponds to 49.2 indicated horsepower per 100 cubic feet of piston displacement of the

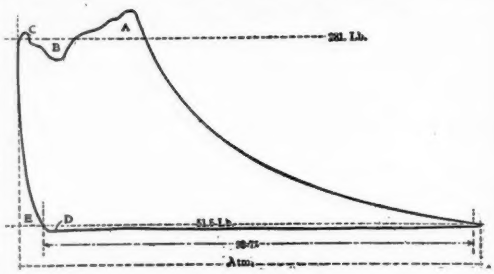


FIG. 2.

compressor. There is, however, another factor which enters here; that is the volumetric efficiency. If 100 cubic feet of piston displacement of the compressor actually delivered 100 cubic feet of gas measured at the intake pressure, this would be the horsepower per 100 cubic feet, but in this case the volumetric efficiency is 93.7 per cent., or in other words there are 93.7 cubic feet of gas actually compressed and delivered for every 100 cubic feet of piston displacement of the compressor. It is, therefore, necessary to divide our figure 49.2 by 0.937, giving an answer of 52.4 indicated horsepower actually developed in the compressing cylinder per 100 cubic feet of gas actually compressed and delivered from the cylinder per minute, measured at the intake pressure of 51½ pounds per square inch.

Now, as already said, the theoretical power required for adiabatically compressing natural gas from 51½ to 281 pounds is 49.9 indicated horsepower per 100 cubic feet per minute and, therefore, the efficiency of compression will be the ratio of 49.9 to 52.4, or 95.3 per cent. In other words, although as in all good compression work, the compression curve falls below the adiabatic compression line, the excess area of the indicator card as shown above the discharge line at *A* and *C* in Fig. 2 and also the area underneath the intake line at *D* in the

same figure, do actually make the indicator card greater in area than it would be if the compression line followed the true adiabatic line and were cut off square at the top along the discharge line and at the bottom along the intake line. The areas *A* and *C*, as said, tend to increase the area of the card, whereas the area *B*, which is due to a pulsation of the pressure in the pipe line, and the area *E*, which is due to re-expansion from the clearance space, both tend to decrease the area of the indicator card and bring it down more nearly equal to the theoretical power required.

In this connection it may be noted that the volumetric efficiency, while it means a decrease in the quantity of gas delivered by a machine of a given size, also means a decrease in the power required to compress this gas by an amount equal to the area *E* shown in the card, and this reduction in area is almost exactly the same as the reduction in the quantity of gas compressed, so that loss of volumetric efficiency means very little loss of power efficiency.

The compression efficiency shown by this particular card is very good indeed, as it is no unusual thing to find this efficiency for some of the poorer grades of compressors as low as 85 per cent. As said, this efficiency depends upon the valve area and speed of the compressor, and it is also very materially affected by the ratio of compression; that is, the absolute discharge pressure divided by the absolute intake pressure, or the number of times that the pressure is increased in the process of compression. The higher the ratio of compression the higher the efficiency of compression, because as the useful power increases, the area of lost work shown on the indicator card bears a smaller ratio to the whole. It is, therefore, important that the efficiency of compression for different compressors should be carefully compared under the same conditions of compression ratio, and also compressor speed.

This is all very well, but what does this have to do with the pulsation diagrams shown as taken from the compressor-discharge pipe? It is just this: The efficiency of compression can be calculated only when the actual discharge pressure is known, and it very seldom happens in a compressor station that the pressure gage reads anywhere near the correct figure. Its error may be anywhere from 1 to 10 pounds, or even more, and it is also usually piped up at such a great distance from the compressor that the reading, even if the gage is carefully calibrated, is not the true discharge pressure of the compressor at the discharge pipe where the compressing cylinder delivers the air or gas.

If, in order to eliminate these losses of pressure drop in the pipe line after the gas or air has left the compressor cylinder, which losses should not be charged against the compressor, the pressure gage is placed on the discharge pipe close up to the cylinder, the pulsations of the gage hand caused by the air pulsations, which we have said so much about already, will make it impossible to get an accurate reading of the true discharge pressure, even if the gage itself is accurate. The only thoroughly satisfactory way to obtain the actual discharge pressure for careful calculation is to put an indicator upon the discharge pipe, as already described, and to take these diagrams of the pulsations in the pipe.

It must be understood that the indicator must be positively driven from the compressor mechanism just as the regular indicator on the cylinder is driven in order that a true diagram of the pulsations taking place with each stroke of the compressor may be obtained. If the indicator string is pulled by hand without regard to the motion of the compressing piston, the diagrams obtained will never be twice alike, and moreover the instrument will not form a closed diagram, which it should, of course, do. The only proper way to do this is, then, to drive the indicator on the discharge pipe from the same source as the indicators on the cylinder, that is, usually from the crosshead.

CALCULATING RESULTS.

After our diagram of the air pulsations has been obtained, how can we obtain the actual discharge pressure? Turning back to Fig. 1 and looking at diagram *A*, we will see at each end of the atmosphere line, a perpendicular erected. Now using a planimeter and starting in, say at *X*, we can follow up the vertical line until it comes to *Y*. At this point continue farther up with the pointer and follow around the upper line, as shown by the arrows, to *Z*, where the other line is crossed. Continue along the underside of the right-hand end of the figure 8 until you come to *W*, and at this point turn sharply down along the perpendicu-

lar leading to the other end of the atmosphere line at *V*, and finally back along the atmosphere line to the point *X* where we started. Let us assume that the area thus obtained is 4.05 square inches.

Again starting at the point *X*, follow up the vertical line to *Y* and at this point turn sharply to the right along the lower side of the left-hand end of the figure 8, coming again to *Z* where the other line is crossed. Following along the upper side of the right-hand end of the figure 8 we come to *W*, and from here we go down the perpendicular to the atmosphere line and finally along the latter to the point *X* from which we started. Let us assume that the area thus obtained will be 4.01 square inches. The average of these two areas is 4.03 square inches.

Measuring the length of the diagram we find it to be 2.69 inches. If the average area of the diagram *X Y W V* is 4.03 square inches and its length is 2.69 inches, the average height will be 4.03 divided by 2.69, or 1½ inches. If now a line *Y Z W* is drawn 1½ inches above the atmosphere line *XV*, this will truly represent the average pressure shown by the figure 8 curve, which is, of course, the true average pressure in the discharge pipe. If the scale of the spring is 60 pounds to the inch, this line 1½ inches above the atmosphere line will represent 90 pounds pressure.

This gives an accurate means of calculating the theoretical power to the exact pressure at which the air or gas is being delivered from the compressor and, comparing this theoretical power with that actually obtained by an indicator on the compressing cylinder itself, the true efficiency of compression of the machine may be obtained.

For diagrams such as the others shown in Fig. 1, which are somewhat unusual in their extreme number of vibrations, an easy way to obtain the average height is to traverse the planimeter point along the wavy diagram halfway between the two lines, of course crossing both lines each time the two lines cross each other. This is especially easy where the lines follow each other very closely, as in diagrams *B, D, E* and *F*. Although this method is not quite so accurate as it would be to follow out each separate wavy line by itself, taking an average of the two areas thus obtained as we did for Fig. *A*, a little practice will develop sufficient skill to obtain results in this way just about as accurate as if each line were followed separately.

This average method cannot be adopted in such a diagram as that shown at *A* because, as the lines cross each other at one point only, *Z*, if we are to try to follow the middle line through the figure 8 with the planimeter point, we might as well draw the average pressure line in with a pencil by guessing at it and then measure the distance. Such a procedure, of course, at once destroys all the accuracy that it is desired to obtain by the use of the diagrams and the planimeter instead of the ordinary pressure gage.

This study of the efficiency of compression of various compressors under various conditions of ratio of compression, speed and valve area is exceedingly interesting, and it is a subject well worthy of careful investigation. By this means only can a true estimate be made, with sufficient data at hand, to determine just how much valve area the compressor cylinder should have for a given set of conditions to give a certain efficiency of compression and consequently facilitate the making of accurate guarantees of performance on the part of various manufacturers.—*American Machinist.*

A REFRIGERATING TURBINE

A French inventor has constructed a refrigerating machine of entirely new type. This machine consists of the combination of a steam ejector with a turbine used as a condenser. The steam ejector used with the condenser produces a vacuum over a receiver filled with brine; the water, as it evaporates, produces a progressive degree of refrigeration. The steam jet, as discharged from the ejector, enters a receiving chamber, where the steam passes through a series of converging tubes, which at their outlet end are again made to diverge. Thence the steam reaches the condenser, which is a reversing turbine with the injection of water at the centre. The steam from the ejector, together with that from the brine vessel, which is carried over along with it, becomes condensed in the turbine. A centrifugal pump, keyed on the same shaft as the condensing turbine, causes the active circulation of the brine. The constant vacuum maintained in the receiving vessel helps to draw in brine. The steam pressure at the ejector is 4½ lbs., and in expanding it assumes a speed of 3,900 ft. per second.

RECORDING METER FOR AIR OR GAS VELOCITIES

The accompanying cut, reproduced from Metallurgical and Chemical Engineering, shows the design and principle of action of a recording gage for showing the velocities of flue gases, but apparently applicable also to the gaging of the flow of compressed air in pipes. For the latter purpose, no matter what the air pressure, it would seem that the entire apparatus might be enclosed in a chamber subject to the pressure, and then its action should be the same as when subject to simple atmospheric conditions.

The gas whose velocity is to be measured flows through the flue shown in the right hand and in the direction of the arrow. Within the path of the gas the ends of two pipes, R_1 and R_2, are placed, the ends of both being bent but in opposite directions. This causes a difference of pressure being caused by and being dependent solely on the velocity of the gas, and by measuring this pressure difference the velocity of the gas is determined.

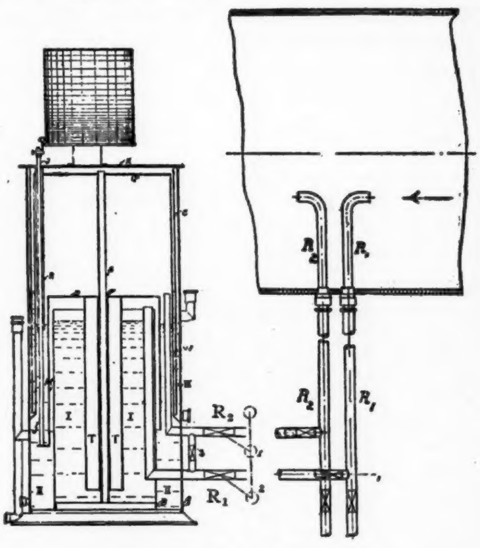
The pressure difference is measured in the apparatus shown at the left. It consists in the main of two cylindrical compartments, one within the other. Both are partly filled with liquids, of which the inner one serves as operating medium and the outer one as a water seal. The inner liquid *I* carries a float *T* to the top of which is fastened an inverted cup-shaped cylinder *D*, which dips with its lower open rim *M* into the outer sealing liquid *II*. In this manner two independent gas chambers are formed, both of varying capacity, depending upon the depth of the immersion of the bell, which in turn depends directly upon the variation of pressure within and without.

A rod *S* that is centrally fastened to the bottom of the main cylinder serves as a guide for the operating bell. Its upper end passes through the removable cover plate *P* of the apparatus.

The movement of the float or bell is carried outwardly by means of a second rod *J*. This rod is hinged to the lower portion of the bell and it passes through a tube *R*. The top end of this tube is secured air-tight to the cover, and its lower end dips into the sealing liquid *II*. The rod carries at its upper end a writing pen which bears against a rotating cylinder operated by clockwork, and this serves to trace the varying differential pressures of the system upon a chart.

An additional water seal *W* is provided for the cover by a cylindrical portion *C* extending therefrom downwardly into the sealing liquid *III* of an annular space, formed within the upper portion of the main body.

Communication between the gas main and the apparatus is established by two pipes R_1



RECORDING GAS VELOCITY METER.

leading into the air space below and R_2 leading into the space above the movable bell. Each of these pipes is provided with a stop-cock, 3, and both cocks are linked together to make them work simultaneously. By these means it is made possible to distribute the pressure to both sides of the bell at the same time. A three-way cock serves to make communication of both air spaces in the apparatus with the atmosphere.

The filling of the three independent liquid chambers is accomplished through pipes which lead out from the main body of the apparatus Plugs are provided for at the lower end of these pipes, which allow easily draining the receptacle if this should be necessary.

The velocity of the gas in the flue causes, as explained above, a difference of pressures in the two pipes R_1 and R_2, and this pressure difference causes the movement of the bell which is transmitted to the writing pen on the recording device.

This apparatus, which is made by the Hydro

Manufacturing Company, Pittburgh, Pa., is designed to be used in gas works, producer gas installations, coke oven plants, blast furnace plants, and in general in metallurgical and chemical works in which the success of the process depends on a definite rate of supply of air or gas. Naturally the instrument is also useful in boiler plants, where it is employed to check the correct air supply for the most economical combustion of the coal; in this case the record chart indicates every operation of the fireman or of the automatic stoker, and serves as a guide to the fireman in which manner to obtain the best results.

EFFECTS OF HIGH TEMPERATURE AND HUMIDITY IN MINES

George J. Young, Professor of Mining and Metallurgy in the University of Nevada, in an interesting paper before the American Institute of Mining Engineers, says that while much has been written about the effects of poisonous and other gases upon the human system, very little occurs in mining literature concerning high temperature and humidity. He then quotes samples of what has been written in this line.

Le Neve Foster says: "In still and saturated air it is hardly possible for men to do continuous work above 90 or 95 deg. F., even when stripped to the waist. At higher temperatures in saturated air the amount of work possible becomes less and less, and the body temperature may rise rapidly, though men accustomed to the heat can bear it much better than others. At temperatures above 90 deg. it becomes difficult to remain even without working. Thus, at a temperature of 93 deg. in still and saturated air I found that, though I was stripped to the waist and doing practically no work, my temperature rose 5 deg. in two hours, and was still rising rapidly when I found it necessary to come out. On the other hand, it is a well-known fact that if the air is dry much higher temperatures can be borne with ease and comfort. In collieries where the air is fairly dry and in motion, men can work well at a dry-bulb temperature of 90 deg., or even 100 deg., and in hot climates with very dry air much higher temperatures are not oppressive."

AS TO PERMANENCY OF EFFECT.

The following is the conclusion of Eliot Lord: "The ultimate effect of this extreme heat on the miners' constitution is not so easily noted. The mine levels differ materially in temperature, and the assigned station of a miner is so frequently changed from one cause or another that it is impossible to obtain at present complete comparative data. That prolonged labor in hot, impure atmosphere will assuredly shorten life appears indisputable; but whether the system is permanently or materially injured by intermittent working under those conditions is more questionable. The power of recuperation appears extraordinary, and unless the strain is intense and frequent no lasting injury may be inflicted. The limits of permissible strain vary with the relative power of endurance. The action of all the bodily organs appears to be stimulated by the heat, with the exception of the stomach alone."

NO LUNG TROUBLES.

Messrs. Haldane and Thomas comment on exposure to high temperatures and to sudden variations of temperature as follows: "Miners are exposed to high temperatures underground and to comparatively sudden cold on coming out, often with damp clothes on. Much stress has been laid upon this fact, particularly in relation to lung diseases. Nevertheless, this cannot be an important cause of lung diseases, for colliers are similarly exposed. Moreover, in England colliers never wash or change their clothes at the pit head, while Cornish miners invariably do so in a heated building (dry) provided on the mine. The effects of high underground temperatures on men and horses are certainly of considerable interest and economic importance, and we know from personal observations that in warm and moist air underground the body temperature often rises several degrees; but we can find nothing in the circumstances connected with the mode of occurrence of miners' phthisis to suggest that high underground temperatures are in any way connected with its causation."

Church states his final conclusions as follows:

"The casualties positively traceable to heat are therefore 12 per cent. of the whole. Probably the heat increases the bad effects of the powder fumes and natural gases, and by making repairs to the shafts more frequently necessary it indirectly adds to the occasions when disasters may occur. I also confess to the belief, which is not sustained by observations upon specific casualties, that some allowance must be made for a less active mental con-

dition, a dulling of the faculties and a certain recklessness to which the heat sometimes goads the men. On the other hand, heat makes them more careful, except when under momentary impulses, and I have never seen American miners more careful of themselves than in these mines. On the whole, the good and bad effects of heat seem to nearly balance each other, and I think that an allowance of 5 per cent. for the casualties indirectly caused by heat would be sufficient."

The main facts brought out by these observers, says the author of the paper, are that high temperatures and humidities cause, under some conditions, a notable rise in body temperature, that all the bodily organs with the exception of the stomach are stimulated, that prolonged exposure to such conditions undoubtedly lowers vitality, that intermittent exposure produces no permanent ill effects, that these conditions cannot be considered an important cause of lung diseases, and, lastly, that under abnormal conditions loss of mental control and serious bodily disturbances result.

Local physicians inform me that the average life of the Comstock miner approximates 25 years, and that the miners do not show any greater susceptibility to any particular disease than the residents of the town. I am acquainted with miners who have worked more or less continuously underground for 30 years, and who are still capable of doing a good day's work. Compared with miners of other districts the Virginia City miners may be said to be just as healthy, if not more so. The result is due in a large measure to the fact that the Virginia City miner observes certain precautions, and that the mine-managements provide the necessary facilities.

MINERS' PRECAUTIONS.

Miners are careful not to expose themselves to cold drafts, since they work stripped to the waist. On passing from a hot to a cold place a heavy coat is used to protect the heated body. Wet clothes are either removed before going to the surface, or trousers and coat worn over them. All miners take hot and cold showers after coming off shift. Frequent drinking, and the bathing of the hands, wrists, arms, and head in ice-water is resorted to in all hot workings, and undoubtedly serves to keep down the body temperature, while temporarily refreshing. Frequent rests are taken in special cooling-rooms, so placed in the workings as to receive the freshest and coolest air. In exceedingly hot workings cold water from a hose is turned upon the miner while at work.

The effect of the underground conditions upon the blood was made the subject of a preliminary study by Prof. P.. Frandsen at my request. His conclusion, given tentatively, is that "the conditions in the deep workings of the Virginia City mines do not have any particularly detrimental effects upon the composition of the blood. It appears that the main permanent effect is an increased hemoglobin content of the individual red-blood corpuscles."

COMFORT AND EFFICIENCY.

Conditions are not favorable for a study of the comparative efficiency of miners working under normal temperatures and under those in the lower levels of the Comstock. The following conclusions are the results of my underground experience.

(1) Moderately high temperatures, from 95 deg. to 105 deg. F., with moderate humidities from 50 to 70 per cent. relative humidity, and with air currents of velocities from 200 to 300 ft. per. min., do not prevent efficient work nor are they particularly uncomfortable.

(2) A higher temperature, from 110 deg. to 115 deg., together with the same conditions as above, decreases efficiency to a considerable extent.

(3) A high temperature, from 110 deg. to 115 deg., with high humidity and a moderate velocity air current, very greatly impair the miners' efficiency, and a still higher air velocity, under the same conditions, renders workings more bearable, but miners cannot work very long at one time.

(4) A moderately high temperature, from 95 deg. to 105 deg., in a saturated atmosphere with no current, becomes very trying. Prolonged exposure with much exertion is dangerous.

(5) A moderate temperature, from 90 deg. to 98 deg., in saturated air currents of a velocity from 400 to 500 ft. per min., and with more or less vitiated air, are conditions which are very trying and give a low labor-efficiency. Vitiated air will impair labor efficiency to a greater extent than a high temperature.

A chair in aerial navigation has been established at the East London College of the London University.

AUTOGENOUS WELDING

A number of trials have recently been conducted with the autogenous welding process at the plate mills of the Schulz Knaudt Company, Essen. The chief advantage of this process is that the joint, if desired, can be made thicker than the rest of the material (plates), so that it will not be the first portion to give way under tension or compression strains. Certain precautions are necessary to the attainment of successful results; the acetylene, for instance, has to be free from any lime dust or other impurities, and the burner must be large enough to ensure that the gas does not issue with excessive velocity, and to prevent working with an excess of oxygen. The added metal must be of the best quality, and the drops should not fall into the joint until the material there has been fused by the burner. In the absence of this precaution no proper weld can be obtained, the adhesion between the metals being only like that between wood and sealing wax. Finally, continuous hammering of the added metal is necessary, and careful annealing of the joint; if possible, the joint should be welded from both sides of the plate.

In testing the strength of joints welded by the autogenus process, no proper criterion can be obtained by taking test bars that have been worked on all sides, especially when the projecting metal at the joint is filed down flush with the rest of the material. If the joint be left untouched, the test piece will break at some other place when the tensile strength of the material is exceeded; but when the joint has been weakened by filing it may break first, contrary to what would happen in practice. Moreover, filing does not improve the elongation, as it does in the case of pieces welded by the water-gas process, where the joint is thinner than the rest of the material.

For the purpose of carrying out the tests in question, a dome-ended boiler, 4 ft. in diameter and 5 ft. long, was constructed of 0.6-in. plate, there being one longitudinal and two transverse joints, all welded by the autogenous process. The finished boiler was subjected to an internal hydraulic pressure considerably in excess of the mean breaking strength of the boiler plate used; but no leakage was produced in any of the joints. The boiler was afterwards cut up, and specimens of the plate and joints were tested, with the result that the weakest worked specimens did not break until a tension of 48,400 lbs. per square inch was reached, as compared with 55,000 lbs. for the plate, and a minimum of 53,000 lbs. for the unworked specimens. The elongation ranged from 6.5 per cent. to 21.3 per cent. for the joint specimens, and from 27.3 to 29 per cent. for the plate specimens.

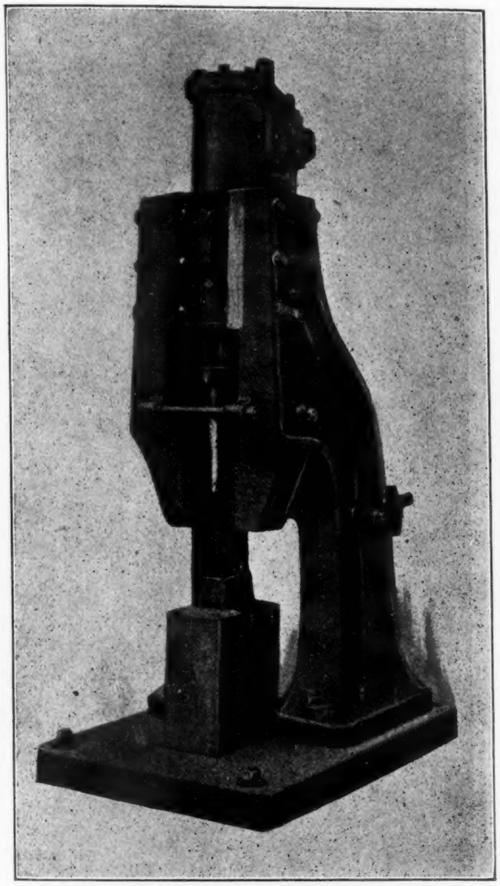
In another series of tests a cylindrical tube, 34 in. in diameter and 40 in. long, was made from 0.4-in. plate with one longitudinal joint. This tube was corrugated on the Fox pattern, made red hot and rolled plain, and then corrugated on the Morison pattern, this giving corrugations in different positions from those produced at first. This tube gave test result quite equal to those furnished by a similar tube welded with water-gas.

AUTOMATIC HIGH SPEED PNEUMATIC HAMMER

The half tone and the sectional cut here reproduced from *The Engineer*, London, show the essential features of the new development of the pneumatic forging hammer as produced by the firm of Peter Pilkington, Limited, Bamber Bridge, England.

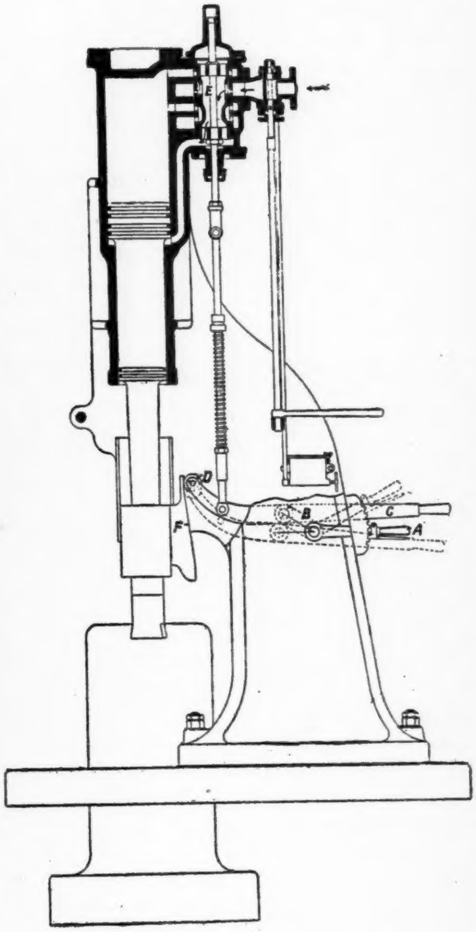
This hammer has been designed in recognition of a demand which exists for a pneumatic hammer capable of working at high speeds and which can be set to run automatically with various strenghts of blow. The principle on which the hammer works is the same as that of the ordinary forge type produced by the same firm and described in COMPRESSED AIR MAGAZINE, October, 1907. The air cylinder is of considerable length, bored out to two diameters, and at the upper end of the tup there is formed a piston head, working in the upper or larger power cylinder, while the smaller cylinder acts as a guide. Air is admitted under the piston into the upper cylinder for lifting the tup only, and this same air on being exhausted is expanded on the top side of the piston for striking ordinary blows. When a heavy stamping blow is required, the operator can utilize the full air pressure on top of the piston. It should be pointed out, however, that for striking dead blows the lifting area of the piston is in communication with the air supply, as well as with the space on top of the piston, or, in other words, both sides of the differential tup are in communication with the air supply.

In the ordinary pneumatic hammer made by this firm there is only a single operating lever, which serves for all strengths of blow, light or heavy, and also for holding up or down. In the high-speed type illustrated there are provided two levers, one to give the time blow, and the other to fix the automatic blow for any degree of intensity. The self-acting motion consists of the quadrant lever A, which is rigidly connected to a crank or



AUTOMATIC PNEUMATIC HAMMER.

movable fulcrum pin B. This supports another lever C, carrying a roller D at the end, which also operates the piston valve E. When the quadrant lever is in its lowest position—shown in full lines—the movable fulcrum pin will be in its highest position, so that when the air pressure is turned on the tup will rise, and the lever carrying the roller will also rise on the inclined slide F. The piston valve will thus be raised, allowing the air to flow to the top side of the piston, when the tup will be driven downwards. This cycle is repeated automatically so long as the air supply valve is open. When, however, the quadrant lever is moved to its highest position—shown in dotted lines—the fulcrum pin is brought to its lowest position, and this



SECTION OF CYLINDER AND VALVES.

lowers the lever and the piston valve. In this case the air is again admitted to the lower side of the piston, and the tup rises to its top position; the inclined slide again lifts the lever and valve, but, since the latter was lowered by the quadrant lever, the valve will not be raised to the same height as previously, and the port to the top of the piston will re-

main closed. The tup therefore remains in its highest position. When it is desired to operate the hammer by hand, or to strike dead blows, it is only necessary to operate the hand lever C, and thus move the valve, the quadrant lever in the meantime being fixed in its highest position. The force of the blow when the hammer is working automatically is thus regulated by varying the position of the quadrant lever.

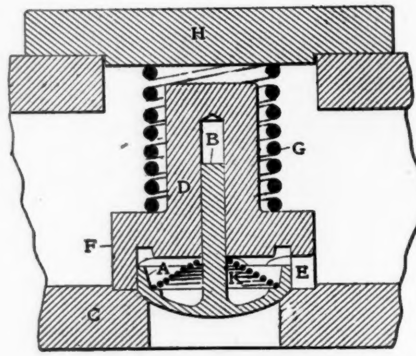
Attention should be called to the method of securing the cylinder between the two standards, the cylinder being provided with two keys, which form part of the cylinder flanges. These keys fit into corresponding recesses in each standard, and take the shear off the bolts which hold the parts together. This type of hammer is made in sizes varying between ½cwt. and 7½cwt., and the number of strokes per minute varies between 300 in the smallest to 150 in the largest sizes.

A COMPRESSOR DISCHARGE VALVE AND A CRITICISM

Those unfamiliar with compressed air practice, and especially with the compression of the air, cannot be expected to appreciate the complexity of the problem or the multiplicity of conditions, many of them apparently conflicting, to be satisfied, or often rather to be compromised or reconciled, to secure the best results. Great progress in compressor design has been made in the last score of years and the study of compressor details is as active as ever. Among the most responsible details of the compressor are the discharge valves, and valves in great number have been devised and successively tried and the work of promoting the survival of the fittest still goes on.

A new discharge valve for air compressors, the invention of Mr. C. A. Dawley, is shown in the cut and we abstract here some of the descriptive matter, presumably written by the inventor himself, with which the valve was presented to the readers of *The Engineering and Mining Journal* in a recent issue. It is suggested that compressors should be run much faster and it is asserted that "the expert on compressors will tell you that the cause of the speed limitation in all sizes of air compressors, except the very large ones, is due to the sluggish action of the discharge valves." Then follows the description of the new valve which should be capable of more rapid action.

"A" represents the valve proper; *"B"* is a small guiding stem which serves merely to steer the valve in its motion; *"C"* is the seat or portion of the cylinder in which the valve rests; *"D"* is the guide for the valve and stem and also serves as a stop for the outward motion of the valve; *"E"* is one of a series of ports in the circumference of the guide; *"F"* is one of a series of legs which come between these ports and center the guide upon the seat; *"G"* is a heavy spring which is intended only for holding the guide down in its place



DAWLEY DISCHARGE VALVE.

without the necessity of making a rigid connection between the guide and the cover *"H."*

It will be observed that the diameter of the grinding portion of the valve is considerably in excess of the diameter of the opening which is the nominal size of the valve. It will also be noted that the valve is very light in weight because of the fact that the guiding portion is short. This guiding portion does not need to be of any greater length because the valve is held to its proper direction by the stem *"B."* In operation the top edge of the valve guide passes back and covers the edge of the ports *"E"* in the guide. Whatever air is between the valve and guide at this point is thus inclosed and acts as a cushion to bring the valve gradually to a stop, and this in turn builds up a pressure back of the valve which assists in returning it to the seat. The spring may consequently be light and the resistance to the flow of the air through the valve is very little. This valve operates almost noiselessly and is capable of a high rotative speed.

The usual speed of compressors ranging all the way from 4 to 24 in. stroke, does not exceed 150 r. p. m. With this valve, however, there is no reason why compressors should not

be operated up to piston speeds corresponding to those used in steam engines. These valves have been tried out under severe conditions and have proved themselves highly satisfactory. The advantages of this type of valve may be summarized as follows:

Operating Features—(1) Lightness in weight without reduction of strength. (2) Large area of cushion compared to the opening area. (3) Valve guided close to seat. (4) Opening cushioned, making the action of valve free from vibration and pounding. (5) Rapidity of action.

Features of Construction—(1) Valve can be made from a drop forging and submitted to proper heat treatment, then the stem hot-riveted in, and the entire valve finished by grinding. This makes the best as well as the cheapest method of manufacturing. (2) No necessity for perfect alinement between valve cover and seat. (3) Valve cannot be displaced from its seat by distortion due to heat or pressure.

Such a publication as the above of course challenges criticism, and in this instance it was supplied in a later issue of the same publication by Mr. S. B. Redfield. He says:

An essential for an air-compressor discharge valve is that it shall have plenty of guiding surface. The valve shown in the cut, accompanying the article referred to, is exceedingly lacking in guiding surface, as it must depend for this upon the guiding pin *B* in the center and the rim of the valve lip.

An examination of modern valves made by first-class manufacturers will show guiding surfaces three, four or more times as great as given by the design under discussion. This is accomplished by a cylindrical sleeve of large diameter replacing the guiding pin. Furthermore, another essential of the efficient discharge valve is to have free air passage around the rim of the valve. Such construction as the alternate ports and grids marked *E* and *F* in the cut, serves to defeat this, especially if the grids are of any appreciable width. If they are not of any appreciable width the so-called "guiding portion" around the lip of the valve is just that much cut down. Also with narrow grid bars it is easy to imagine a tendency to wear the valve lip in ridges, thus quickly removing any guiding tendency on the part of the grids.

As shown in the cut, it would also appear that the valve spring, which is of conical form, is altogether inadequate. A successful spring, to stand the strain of long and continued air-compressor service, must have more length than would be possible with the construction shown to give enough elasticity, and also greater wire gage to have the proper stiffness.

Next, the claim made for the valve in question that there is effective cushioning above the lip of the rim is rather weak, for this cushioning does not take place until the lip has been lifted up above the top of the ports and begins to enter the shallow pockets in the guide block. The motion after this time is very limited and it is hard to imagine any effective cushioning, especially with the large clearance volume between the valve and guide block. There is, however, some cushion in the chamber *B*, but this chamber is small and without relief to the outside air, so that if the valve were ever positively opened all the way, it would either be against great pressure in *B* or else the air would have to be squeezed out of this space. This squeezing out would tend to hold the valve open due to the vacuum formed by the next downward movement, resulting in delay in the closing of the valve. This effect would be most undesirable, as may be imagined.

Such a suggestion as to make the valve in two parts, that is, by hot riveting the stem in place in the main body of the valve, is extremely questionable. Any valve made in two parts and held together by riveting is practically certain to break apart in a short time. The severe pounding received by these valves in their every-day, continuous operation is more than such construction would stand. First-class manufacturers in these days are cutting their valves from solid material in order to do away with just this feature.

Comparison of weights with effective areas proves nothing unless it is found that, running side by side in actual practice, the new valve will last as long as the heavier valves with which it is compared. Anybody could make a valve which would be extremely light, as this simply means cutting away more metal. The question is, however, how long will it stand the pounding?

The dividends declared by the gold mining companies of the Transvaal for the year 1909 amounted to $47,000,000.

THE AIR LIFT IN A SOUTH AFRICAN MINE

B. C. Travers Solly at the July meeting of the Chemical, Metallurgical and Mining Society of South Africa described a simple air-lift pump used in the May Consolidated mine for unwatering flooded winzes. A two-inch delivery pipe was used, a one-inch air pipe being strapped to it. The air pipe was bent sharply at the bottom and entered the delivery pipe for a distance of three feet. The end was flattened to split up the air currents, giving the greatest possible aeration of the water. The arrangement started with an 18-ft. length of delivery pipe with a bend and short length attached to the top, and as the flow of water decreased fresh lengths were added until the necessity for its use in the winze ceased. The lift at this stage was through a slope distance of 52 ft. in a 40-deg. winze when the surface of the water was 11¾ ft. above the air delivery. The rate of delivery at the start averaged 600 gal. per hour and decreased gradually as the distance between the surface of the water and the air jet diminished. Very little air was required at first but the consumption increased as the water fell. The lift was then moved to another winze and similar results were obtained. The winze was down only a short distance and some one having forgotten to turn off the air one night the water was lowered to a distance of 26 ft. below the discharge of the delivery pipe and only seven inches above the air jet. The apparatus was still at work delivering water in a spray. This describes simply a handy rather than an economical air lift, or, rather, the economy was in the handiness instead of in the actual air consumption.

STANDARDS OF WATER PURITY

A City Council in Oklahoma advertised that the city's spring water was 98 per cent. pure. This would be 20,000 parts of impurity per million. Another city went into the papers with the bold statement that its purifying system was furnishing water that was 98½ per cent. pure. Think of it. Only 15,000 parts impure per million. The absurdity of these boasts may be illustrated by reference to the Steelton (Pa.) water-works. The water there is so filthy that they filter it through coal slack before allowing it to go to the sand filters and yet its maximum turbidity is only 1,600 parts per million. Our city officials in Oklahoma were simply boasting that their water was not more than 9 to 13 times as bad as the very bad water at Steelton. They may learn some day that water that is not at least 99.99 per cent. pure is nothing to brag about.—*H. V. Hinckley, Retiring President of the Oklahoma Engineering Society.*

A NEW EXPLOSIVE

An account of a new explosive, the invention of an Englishman, has been given out by Vice Consul General Claude E. Guayant of Panama.

The inventor's exhaustive tests before the members of the Isthmian canal commission and officials of the republic of Panama, showed that it is absolutely impossible to explode it by ordinary means. It was hammered with a sledge, shot into with a rifle, burned and ordinary dynamite detonators were exploded in it, both by fuse and electricity, but the compound was inert. Not until a special detonator was inserted could the substance be exploded; but then, in a few charges that were set off, it showed itself more powerful than dynamite. It can only be set off by heating a small platinum wire just inside the open end by an electric spark or fuse. It will not explode by concussion. The new explosive is composed of perchlorate of ammonia, nitrate of soda and several other ingredients, such as paraffine, for water proofing, etc. It is claimed that it is 50 per cent. stronger than the 60 per cent. grade of dynamite, and that the cost of manufacturing will be more than $20 a ton cheaper.

COST OF AIR NITRATES

Calcareous nitrogen containing twenty per cent. nitrogen costs for its production from $47.27 to $55.15 per short ton. This makes the actual nitrogen in the compound cost 11.8 to 13.6 cents per pound, while the cost of the nitrogen in compounds formed by the direct combination of the elements in the air is generally conceded to be less. The experiments made with fertilizers of either system, in comparison with Chilean saltpeter, are generally favorable to the artificial product. In sandy soil the calcium nitrate formed by the direct combination of the elements in the air brought even better results than the Chilean saltpeter.

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THE INTAKE PRESSURE IN-AIR COMPRESSOR CYLINDERS

The following correspondence is entirely self-explanatory and should be read with interest. It gives a new start in the discussion of the above topic.

Editor Compressed Air Magazine:

Referring to your December issue and to the reprint of my letter to you regarding the intake "ram" effect, I wish to say that the word "with" on the last line but one should have been "without," as you suggest; it was an oversight in writing.

Noting your suggestion that I might be able to make reply to the questions I proposed, I offer the following which I think is simple enough and leaves out complicated mathematics.

Assume a cylinder of 300 square inches area and 4 foot long and piston speed of about 500 feet per min., so that the maximum piston velocity is 16 feet per sec. Assume a piston inlet pipe 7 inch diameter and 5 feet long such that its content of free air weighs 1-10 of a pound, avoirdupois. The mass of air weighing 1-10 of a pound in this piston inlet pipe while moving at 16 feet per second contains an amount of energy expressed by $\frac{Mv^2}{2} = 4\text{-}10$ of a foot lb. Inasmuch as it will take very nearly 1200 foot lbs. to raise the pressure in the given cylinder to 1 lb. gage we will make no great error in assuming that 4-10 of a foot pound will raise the pressure 1-3000 of an inch. This being a microscopic proposition it could not be measured by an indicator and therefore the explanation of the phenomenon you speak of must be sought elsewhere.

E. A. Rix.

San Francisco.

A copy of this letter was submitted to the writer below, with the result here given.

Editor Compressed Air Magazine:

Your letter of the 3rd inst., together with inclosures, has been received and it has given me great pleasure to study over this matter of the inertia of air entering the inlet pipe of an air compressor cylinder.

From my remarks, made upon other occasions, you know that up to this present I have strongly doubted the inertia theory of accounting for the rise in the intake pressure line of an indicator diagram of an air compressor and

so you will be surprised to find that since I have been studying on this problem the figures which were deduced from such study have caused me to completely change my opinion and to believe that inertia of the air column is responsible for the phenomenon.

First, to take up the problem which Mr. Rix presents, you will note that he considers the air in the inlet pipe to be moving at 16 feet per second. This corresponds to 960 feet per minute as a maximum speed, or assuming an infinite connecting rod this should be the speed of the crank pin in its orbit. With a 4 foot stroke the crank circumference will be 12.6 feet and so, dividing 960 by 12.6 we have 76 r. p. m. of the compressor, which is a reasonable speed for the size machine considered. Now, however, Mr. Rix has assumed that the air is moving through the inlet pipe only at this speed, whereas that is really the maximum speed of the piston at about mid stroke.

Suppose we assume that the inlet area is 12 per cent. of the cylinder area; this would give a speed of the air through the pipe eight times as fast as the piston speed at any point, and as from the formula for inertia as given by Mr. Rix, this depends upon the square of the velocity, the kinetic energy of the moving air should really be 64 times as great as that given. 64×0.4 gives an energy of 25.6 foot pounds for the quantity of air considered in the inlet pipe.

Apart from this Mr. Rix has considered an inlet pipe only 5 feet long. It seems to me that 15 feet would be more reasonable, wherefore, multiplying by 3 we have 76.8 foot pounds, as the probable energy of this air.

Now to turn to another method of figuring this inertia. You know that many writers on engine design give formulas for figuring the net force for starting and stopping the reciprocating parts at the beginning and end of each stroke. Most of these writers give these results for an engine with an infinite connecting rod. Under these conditions the formula for the starting and stopping force is as follows:

$$F = \frac{W \Pi^2 N^2 R}{900 g}$$

In this formula W is the weight of parts in pounds, N is the number of revolutions per minute, R is the crank radius in feet, g is the acceleration of gravity, or 32.2.

Further study of this problem will reveal the fact that this force is the same as the centrifugal force which would be exerted by an equal weight of material, revolving on the crank pin at the speed given. An explanation of this is given on page 226 of Charles T. Porter's Treatise on the Richards Steam Engine Indicator. It will also be found in other books on engineering.

If the finite length of the connecting rod is taken into account it will be found that this starting and stopping force of reciprocating parts is even greater than given by this formula. Professor Jacobus, in the transactions of the A.S.M.E. Vol. 11, page 492, and 1134 gives factors by which various lengths of connecting rod may be taken into account. If the rod is equal to five cranks, the force calculated by the above formula would be multiplied by 1.2, so that by this you see we are on the safe side if we use the formula for the infinite connecting rod.

Now going back to our original problem: with 3/10 of a pound of air in an intake pipe 7 inches in diameter by 15 feet long and letting the 4 foot stroke compressor be making 76 r. p. m. and substituting in the above formula we find that the force exerted at the beginning and end of the stroke by this air is 1.18 pounds. This does not seem unreasonable when we consider the swinging of a weight of 3/10 of a pound on the end of a 2 foot string, at the rate of 76 revolutions per minute. We can easily imagine the pull would be about one pound, as calculated.

So far we have assumed that the air in the inlet pipe is moving only as fast as the reciprocating parts of the compressor, but, as before, assuming a 12 per cent. inlet area the air will travel eight times as fast. This can be taken care of in the formula by assuming simply that the crank radius is eight times the real radius. This is perfectly logical when it is considered that the horizontal component of the speed at the end of the longer radius at every instant will be just eight times the horizontal component of the speed of the shorter radius, each passing through zero at the end of the stroke and reaching a maximum at the centre of the stroke. Also, the number of reciprocations is unchanged.

As the formula gives the inertia force as directly proportional to the radius of the crank arm, increasing this crank arm by 8 will multiply the force by 8, and consequently we have

the inertia force due to the 3/10 of a pound of air as equal to 9.44 pounds for the entire quantity of air contained in the inlet pipe.

It will be remembered that the inlet pipe is seven inches in diameter and this force is distributed over this whole area of 38.5 square inches. Dividing 9.44 by 38.5 gives 0.245 or just about ¼ pound per square inch pressure exerted by this air in the inlet pipe at the beginning and end of the stroke. This result seems to check very well with most of the indicator diagrams which I have seen showing this rise in pressure.

From the above is meant that a quarter pound above the atmosphere is as much as is ever seen; of course it may be argued that the total rise from the intake line is much more than this. This may be easily accounted for by reasoning that as the piston slows up at the end of the stroke, the moving air catches up with the piston and by the time the piston comes to rest, even if there were no inertia, the pressure should be approximately atmospheric, if sufficient valve area were allowed.

Such an inertia effect at the end of the stroke should also be visible at the beginning of the stroke; and what is a more plausible explanation of the decided hook in the clearance expansion line at the point where the intake valve opens, than the inertia of the air in starting into the cylinder?

Many people lay this hook to the inertia of the indicator parts, and no doubt some of it can be laid to that cause, however, I am firmly convinced that inertia of the air has much to do with it, because of some indicator diagrams taken on the very low pressure Post Office compressors in Philadelphia by myself. There, an eight pound spring was used, and, although the drop of the indicator pencil was only about half an inch maximum and the mechanically moved inlet valve was wide open, as determined by actual inspection, a hook of two or three pounds drop at the beginning of the suction stroke, absolutely could not be eliminated. There seemed to be no explanation for this except an air pulsation produced by inertia only.

It may be contended that even after we have re-figured Mr. Rix's results, giving 76.8 foot pounds of energy present in the air in the intake pipe and remembering that, as he said, it will require 1200 foot pounds to raise the pressure of air in the cylinder to one pound pressure per square inch, or about 300 foot lbs. to raise it to one-quarter of a pound per square inch, there does not seem to be enough energy present in the moving air to account for the work done.

A plausible answer to this would seem to be that the air in the pipe is flowing and more air is continually coming in from outside, this air having energy of velocity added to it by the steam engine of the compressor itself. This energy is given up to the air inside of the cylinder during all the time that the piston is slowing up toward the end of the stroke and therefore more energy in foot pounds is actually delivered to the air inside the cylinder than is represented by the volume of the intake pipe only.

It may further be contended that this argument could be applied to the formula giving the force of retardation, as worked out. This is true, but this would not change the force. The pressure would still be one-quarter of a pound per square inch at the end of the stroke, and the fact that the air has been flowing into the cylinder with gradually increasing pressure, up to the maximum of one-quarter pound per square inch, would account for the performance of the relatively large amount of work performed upon the air, this being the product of force and distance.

It certainly must be conceded that as the actual force is shown to be present simply from the reasoning of accelerating force alone, as applied by enginering calculators to the force of the reciprocating parts, the air in the cylinder will yield to this force and build up a pressure equal to it to resist its action, the energy to do the actual work coming from the volume of air flowing through the pipe during the latter half of the stroke.

This explanation is rather long, but by this course of reasoning my own ideas of the subject have been so completely reversed that no shorter line of reasoning would seem satisfactory.

Thanking you for this opportunity to think over this matter and to express my opinion on the subject.

S. B. Redfield,
Associate Editor American Machinist.
New York City.

MEASURING THE FLOW OF COMPRESSED AIR

One of the things at present most to be desired in compressed air practice is some practical and reliable system or apparatus for measuring the volume of air during transmission. We can ascertain both pressure and temperature with any desired accuracy, but the volume during transmission is more elusive, while upon it, in connection with the others, depends all accurate knowledge of capacities and efficiencies, and also of the rate of consumption and ultimate costs of operation in different lines of service. Contributions to our stock of knowledge in this field are accumulating and they are all to be welcomed. In our present issue is described an apparatus intended primarily for the measuring of the flow of flue gases, but apparently applicable also to compressed air, and now we are able to present a statement furnished us by Mr. W. F. Gillies, El Paso, Texas, of certain experiments made by Mr. Legrand, mechanical engineer for the Phelps Dodge interests, at the Copper Queen, Arizona, Mines.

Mr. Legrand has devoted several months to a series of interesting experiments in the measurement of the flow of air through an orifice. He has been testing Flieguer's formula as to its correctness for large volumes. He first with a small compressor proved it up to 1,100 cu. ft. of free air per min., and has since tested it up to 4,000 cu. ft. with a larger compressor, and with a still larger compressor available he is planning to test up to 6,000 cu. ft.

His method is as follows:

1st. Knowing the clearances of the low pressure or intake cylinder he calculates the actual piston displacement, or the free air capacity of the machine.

2nd. He takes indicator cards of the low pressure cylinder, using a light spring, generally four pounds, and measures the actual volumetric efficiency as closely as possible.

3rd. He tests the pipe line to the receiver and the receiver itself for leakage.

4th. Calculates the weight, or volume, of air passing through his orifice by means of his formula.

5th. Checks 4 by 1 and 2.

The formula used in Flieguer's, to be found in Peabody's "Thermodynomics", and is as follows:

$$\text{Wt. of air per min.} = .53 \text{ area of orifice} \sqrt{\frac{P}{T}}$$

P=Abs. pressure.

T=Abs. Temperature.

The orifice, made of brass and polished, was rounded on the side on which the air entered, the radius being equal to the radius of the opening and the length being twice the diameter. The first tests were made with a ¾-in orifice, but in the last test a large one, 1.05-in. dia. was used to show whether the constant .53 held true for other diameters.

The tests of the smallest compressor up to 1,100 cu. ft. checked to within 1 per cent. to 1½ per cent. The following figures will show how near the results obtained on the larger volumes worked out:

No. of Test.	Size of Orifice.	No. of Orifices.	Cu. ft. Free Air Displaced.	Cu. ft. Free Air Delivered.	Volumetric Efficiency by Card.	Volumetric Efficiency by Orifice.
1	¾"	1	1401	1251	94.7	89.3
2	¾"	2	2438	2212	93.8	90.7
3	¾"	3	3513	3217	93.7	91.5
4	1.05"	1	3555	3256	93.7	91.5
5	2-¾" and 1-1.05"	3	4328	4017	94.5	92.8

The air pressure in the receiver was held at between 100 and 101 lb. gage.

It is thought, and the indicator cards show, that there was some leakage back through the discharge valves. This would account for the decrease of difference between the two volumetric efficiencies as the speed increased, and this matter is to be further investigated. The considering in this way the air discharged takes into account all losses due to leakage, the heating of the air entering the cylinder, etc., and the results seem to agree very closely.

SOUTH AFRICAN ROCK DRILL RECORDS

The following records of rock drill work were made on the Rand, South Africa, the

figures being taken from the published statistics of the Mines Department: At the Van Dyke Mine in November, 1908, two 3¼-in. drills drove 323 ft. in 62 shifts of 9½ hours each. This work was performed by two miners named Karlson and Kerr. One white man and five natives worked each shift using two Ingersoll-Sergeant drills. At the New Modderfontein G. M. Co., Messrs. Corris and McHenry, with two 3¼-in. Ingersoll-Sergeant drills, drove during May 267 ft., June 264 ft., and July 295 ft., a total of 826 ft. for 156 consecutive shifts. This was a record for consecutive working. At the same mine, in a 11x8-ft. cross-cut, Mr. Langridge, with two 3¼-in. Ingersoll-Sergeant drills drove 270 ft. in 49 single shifts.

KEEP UP THE PRESSURE IN YOUR TIRES

Automobile experts are quite well agreed that if the riding is easy over rough places and there are no complaints from the occupants of the tonneau because of the jarring then the tires have too little air pressure. If tires are allowed to run continually in this condition the total service may be not more than one-half what it would be if the tires were kept pumped up hard.

"It is simply this way," said James A. Braden of the Diamond Rubber Company recently: "a tire is composed of three parts—the casing or shoe, the inner tube or air chamber and the air itself. We make casings and tubes the very best our twelve years of experience have taught us, but the air must be supplied by the tire user.

"It is a liberal estimate to say that the tire kept well inflated will give twice the service of one allowed to run soft and insufficiently pumped up, though I will grant the softer tires ride more easily. Air gauges are all right, but rules as to pressure fall short of producing the best results if they do not make the tire so hard and firm that there is no noticeable flattening when, with all passengers aboard, the car is ready to start."

MOVEMENTS OF DUST PARTICLES IN AIR

Mr. C. H. W. Biggs in a paper before the Society of Engineers says that one of the most interesting investigations, and one open to every student, is that of the effect of minute air currents upon dust particles. Imagine for a moment dust particles having very large surface compared with their mass. Fortunately, the student can on occasion easily see such particles, and watch their evolutions, in a room where otherwise it is almost, if not quite, impossible to detect air currents by other means. Smoke consists of small particles of matter, and is in daily use to detect minute currents of air both in drains and in rooms. There is an excellent way to investigate and to follow the motion even of individual particles. Dr. Travis, in his experimental work on seeing colloidal matter, makes great use of the ultramicroscope. You can get something of this effect in rooms where a window faces a bright sun. Darken the room, leaving only a hole—preferably circular—through which to get a beam of bright sunshine. Thus we get a cone of brilliant light through the room. In this cone you can see dust particles playing all manner of antics, some falling, some rising, some going in one direction, some in another, the direction of the small masses being the direction of the resultant of the forces acting.

THE LATEST THING IN SAFES

The oxy-acetyline blowpipe may be heard of before long as doing wonders in the hands of safe crackers, and in anticipation of this a new burglar proof safe has been invented in Germany on the carousel or merry-go-round principle. It is a polygonal steel structure mounted to rotate upon ball bearings. It is built into a wall and when the outer door is closed an electric motor is set in motion and the safe turns continually and noiselessly on its axis within, any interfering with its movement causing a bell to ring. So long as the safe continues to rotate the blowpipe can have no effect upon it, as the flame is not applied long enough upon one spot to make an impression.

ELIMINATION OF DUST

A French inventor has devised a scheme for freeing the air in a room from floating particles and microbe-laden dust. A ventilator fan run by electricity turns in a large open Cylinder. Above this is a reservoir holding about a gallon, which can be regulated to let out about a quart per hour. The liquid falls drop by drop on the fan blades. It is then, by the rapid turning of the fan thrown

out in spray against the cylinder. This spray is condensed in drops containing the microbes and dust. As a liquid the inventor employs glycerine, or soap suds, but the plan works very well with ordinary water. The process can be applied to the chemical purification of air, by using suitable chemical solutions for the liquid. The number of microbes contained in water thus collected in the laboratory of the inventor was 100,000 in three hours. The quantity of organic matter per hour was 0.3 grains and of mineral matter, 0.077 grains.

LOCATING AND CURING A COMPRESSOR TROUBLE

The chief engineer of a large plant discovered, upon starting an air compressor which had been idle for some time, that it would only compress to 20 lbs., which was 60 lbs. below the required pressure. After a few futile attempts had been made to remedy the trouble, the manufacturer was notified by wire to send an "expert." In order to appreciate the situation a brief description of the construction is necessary. The machine had two single-acting air cylinders, the plungers of which were connected to the ends of a piston-rod common to both, which passed through the steam cylinder located midway between the two air cylinders. The inner ends of the air cylinders were open, exposing the plungers. One suction and one discharge valve was used for each cylinder. The suction valves were located in the centers of the plungers, and the discharge valves, which were slightly larger in diameter than the bore of the cylinders, covered the outer ends of the latter. The counterbore into the bottom of which each discharge valve seated, was sealed by the cylinder head. A cylindrical projection on the back of each discharge valve, was a sliding fit in the head, and served to keep the valve in position as it moved back and forth. In order to insure a pressure of one atmosphere in the cylinder at the beginning of the compression stroke, three small holes were drilled through the cylinder wall, just ahead of the plunger when it was in position. As these holes were uncovered just before the end of the suction stroke, an inrush of air occurred, the magnitude of which depended largely upon the stiffness of the closing springs for the suction valves. When the manufacturer's "expert" arrived and the compressor was started, it was very noticeable that instead of an inrush of air through the holes of one cylinder, there was a strong discharge to which attention was attracted by the sound emitted. This indicated at once that the cylinder was in communication with the receiver, and it was also evident that the discharge valve was either broken or displaced. When examined it was found to be rusted fast to the head in an open position. Less than a thimble of oil jumped the pressure to 80 lbs., much to the discomfort of the chief engineer.—*Machinery.*

ILLUMINATING GAS POISONING

The poisonous properties of coal-gas are generally attributed to its content of carbonic oxide, especially as no other substance of known poisonous properties has been found in it, and patients suffering from coal-gas poisoning show the symptoms associated with the inhalation of carbonic oxide, including the peculiar bright red color of the blood. From experiments, made by Dr. von Vahlen, at Halle, it seems probable that we must revise this view, for on making experiments with frogs, animals particularly resistant to carbonic oxide, it was found that they were poisoned far more rapidly by coal-gas than by the corresponding amount of the oxide. Other experiments with dogs showed that the poisonous effect of coal-gas was twice or three times as great as that of the carbonic oxide it contained. Evidently there is some other constituent of coal-gas which is poisonous, though what it is cannot yet be stated. Merely removing the carbonic oxide from coal-gas will not suffice to render it non-poisonous.

NOTES

As an example of the rapidity with which the air brake equipment is undergoing change, it is noted that 70 pages of the Proceedings of the Air Brake Association's 1909 meeting were used in describing a new engine equipment that is already superseded by one of an entirely different type.

A German inventor has recently patented a device for milking cows, in which the flow of milk is to be promoted by subjecting the animal to a "slight electric shock." Of the success of the device in practice we are not in-

formed. A jet of compressed air judiciously directed should have some effect on the poor cow, especially in fly time.

A great chemical factory at Höchst on the Main, Germany, exhibited a new metal at the Frankfort aeronautic exposition that is said to be as strong as the best aluminum alloys and but half as heavy. It is called "elektron" and has a specific weight of 1.8 as compared to 2.9 of the best aluminum.

In a recently invented voltmeter, permitting the measurement of tensions up to 200,000 volts, air compressed to fourteen atmospheres constitutes the insulation, as oil would not be suitable for currents of such high pressures. The tension necessary for perforating a layer of air compressed to fourteen atmospheres is stated to be 400,000 volts per centimetre.

The Italian Government is having installed in each of the cities Rome, Naples and Milan, a system of pneumatic dispatch tubes to connect the railroad station, stock exchange, and general postoffice. Each of the installations is to be operated by electric motors and air compressors, a duplicate power plant being provided in every case to act as a standby.

Notices have been sent to the gas companies of the State of New York of a conference to be held in Albany to consider the necessity for a new standard in measuring the quality of gas. The quality is now measured by the photometric standard, by which gas is judged for its illuminating power. This standard has been in use for years. The conference may lead to the adoption of a calorific standard instead.

A French chemist has determined that one ton of dry peat will yield 41 gallons of pure alcohol. After the peat fiber is hydrated it is treated with sulphuric acid and is thus changed into a sort of sugar which when permeated by means of a special yeast yields alcohol. The cost of this method of production is said to be about one-quarter that of potato spirits, so that our large supply of peat may lead to a cheap source of alcohol production.

The total volatile matter in a cubic foot of coal is estimated to weigh 26 lbs.; in this estimate the coal gas is figured at 10 lbs. If steam and air are passed over the 54 lbs. of coke in a producer-gas retort, the result is to generate 4,122 cu. ft.. of producer gas. It is further estimated that 1 ton of coke 90 per cent. carbon, yields 171,000 cu. ft. of producer gas. Acetylene gas is made by fusing the coke with lime in an electric furnace. By this means calcium carbide (CaC^2) is formed.

Germany is to hold an International Congress of Mining and related subjects in 1910. The meeting will be at Düsseldorf, June 20 to 23, and the program is to include discussions on mining, metallurgy, applied mechanics, and practical geology.. Americans are cordially invited to take part. Particulars may be learned from Dr. Schrödter, secretary of the Verein Deutscher Eisenhüttenleute, or Bergassessor Loewenstein, secretary of the Verein für die Bergbaulichen Interessen im Oberbergamtsbezirk Dortmund.

The equivalent volume of free air corresponding to a given volume of compressed air, at the same temperature, and under any pressure may be determined from the following formula:

$$V = V_1\ (0.068p + 1)$$

where

V = volume of free air,

V_1 = volume of compressed air,

p = gauge pressure in lbs. per sq. in.

It is here assumed that our atmosphere = 14.7 lbs. per sq. in., and the constant 0.068 in the above formula is the reciprocal of this.

A gas holder built by the city of Hamburg, Germany, at a cost of $3,500,000 and containing 7,000,000 cubic feet of gas, burst recently and the gas it contained ignited. Seventeen persons were killed and 40 were severely injured. The explosion shook the whole city, and a column of fire blazed hundreds of feet skyward, while huge flames played around the reservoir and neighboring structures. There was no possibility of the workmen escaping. Many of them were killed outright, and others were horribly burned. Three women attendants of the canteen are among the killed. The fire burned dangerously for three hours, during which many neighboring dwellings were ignited.

LATEST U. S. PATENTS

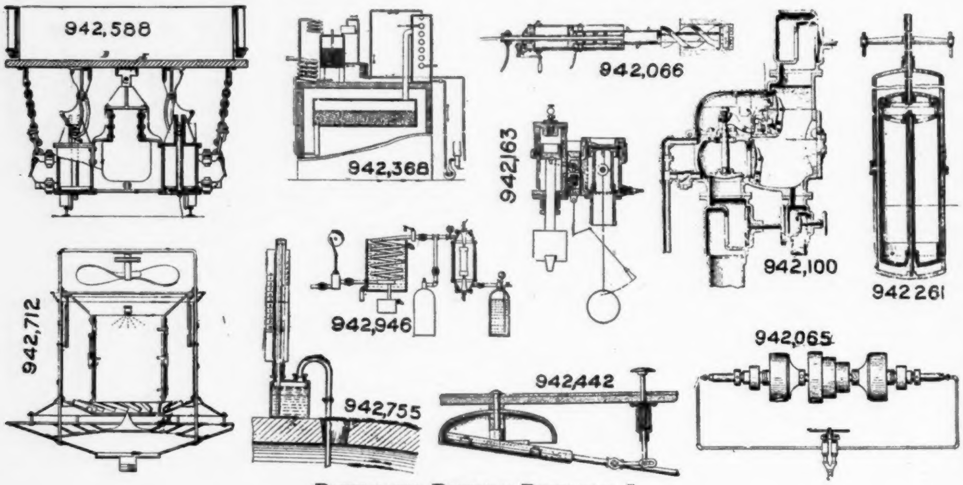
Full specifications and drawings of any patent may be obtained by sending five cents (not stamps) to the Commissioner of Patents, Washington, D. C.

DECEMBER 7.

942,046. PROCESS OF GENERATING AND STORING OZONE. FRANK M. ASHLEY, New York, N. Y.
942,065. PNEUMATIC-OPERATED SHAFT. PAUL J. GREBEL, Chicago, Ill.
942,066. FEED FOR PNEUMATIC TOOLS. MARTIN HARDSOCG, Ottumwa, Iowa.
942,100. DRY VALVE. FRED A. PHELPS, Laconia, N. H.
942,163. PNEUMATIC POWER-HAMMER. AUGUST BERNER, Munich, Germany.
942,261. PISTON FOR HOT-AIR ENGINES. FRANK B. HUBBARD, Middlefield, Ohio.
942,368. AUTOMATIC AIR-TRAP. RICHARD N. DYER, East Orange, N. J.
942,441. FLUID-PRESSURE ENGINE. CYRUS P. EBERSOLE, Keokuk, Iowa.
943,180. INHALING APPARATUS. PETERSON H. CHERRY, Los Angeles, Cal.
943,329. PNEUMATIC-DESPATCH-TUBE SYSTEM. FRANKLIN H. WOLEVER, Chicago, Ill.
943,385. PROCESS AND APPARATUS FOR BURNING OXYGEN WITH OTHER GASES. ARTHUR R. BULLOCK, Cleveland, Ohio.

1. The process of burning oxygen and gas which consists in mingling oxygen under pressure with gas in a mixer, supplying oxygen at substantially atmospheric pressure to the mixture beyond the mixer, and igniting said mixture.

943,422. APPARATUS FOR TREATING GASES AND SEPARATING SMOKE AND DUST THEREFROM. ERNEST G. KNOEPFEL, San Francisco, Cal.
943,424. VACUUM CLEANING APPARATUS. JOHN F. LACOCK, Boston, Mass.
943,426. SUCTION APPARATUS. MAX LEBENBERG, Berlin, Germany.
943,556. VACUUM-PUMP. TOM W. LOWDEN, London, England.
943,583. VACUUM-CLEANER. JOHN N. WHITEHOUSE, New York, N. Y.
943,602. AUTOMATIC AIR-BRAKE RETAINING AND RELEASE VALVE. DANIEL F. KNERR, Newark, Ohio.



PNEUMATIC PATENTS DECEMBER 7.

942,598. DUMP-CAR. HARRY E. THOMPSON, Knoxville, Tenn.
942,712. HUMIDIFIER. FRANK B. COMINS, Sharon, Mass.
942,755. CONTROLLING DEVICE FOR FILLING VESSELS. GUSTAV SCHOLLMEYER, Kothen, Germany.

DECEMBER 14.

942,887. COMBINATION FLUID AND VACUUM CHECK. HARRY T. CASE, Franklin, Pa.
942,891. WET SEPARATOR FOR DUST-REMOVING APPARATUS. RALPH F. DISERENS, Bradford, Pa.
942,915. PNEUMATIC MUSICAL INSTRUMENT. PAUL B. KLUGH, Chicago, Ill.
942,935. APPARATUS FOR DISPOSING OF NOXIOUS GASES. WILLIAM H. SARTAIN, Columbus, Ohio.
943,022. HYDROGEN - GAS GENERATOR. GEORGE F. JAUBERT, Paris, France.
943,023. PNEUMATIC PACKING. EDWIN S. JOHNSON, Oakland, Cal.
943,040. AMMONIA REFRIGERATING APPARATUS. THOMAS C. MCKEE, Chicago, Ill.
943,043. BLOWPIPE. EUGENE ODAM, Paris, France.
943,120. AERIAL NAVIGATION. JAMES MEANS, Boston, Mass.

DECEMBER 21.

943,661. PRODUCTION OF OXIDS OF NITROGEN FROM THE AIR. FRANCIS I. DU PONT, Wilmington, Del.
943,732. AIR-SHIP. AMIEL BRATSCHIE, New Castle, Pa.
943,833. AIR-HEATER FOR AUTOMOBILE TORPEDOES. FRANK M. LEAVITT, New York, N. Y.
943,848. VACUUM-PUMP. FRANK A. SIMONDS, Grand Rapids, Mich.
943,901. WIND-MOTOR. HIRAM W. SMITH, Woolsey, Okla.
943,927. BURNER. JOSEPH GEHRING and RICHARD D. CONRAD, Pittsburg, Pa.

1. In a burner, the combination of a gas reservoir having a wall forming an air tube, and a mixer tube provided with tapering spiral ribs forming tapering channels in communication with said gas reservoir.

943,962. ANEMOMETER. CARL M. BERNEGAU, Hoboken, N. J.
943,983. TRIPLE VALVE FOR AIR-BRAKES. WILLIAM B. MANN, Baltimore, Md.
944,024. AIR-VALVE. HUGH A. FITZPATRICK, Chicago, Ill.
944,029. COAL-MINING MACHINE. ARTHUR H. GIBSON, Easton, Pa.

944,034. PNEUMATIC ACTUATING UNIT. AXEL G. GULBRANSEN, Chicago, Ill.

944,064. FLUID-PRESSURE ENGINE. JOEL W. WEST, Omaha, Nebr.

944,148. WIND-MOTOR. ROBERTO F. E. OKRASSA, Antigua, Guatemala.

944,151. BRAKE MECHANISM. EMIL SANTSCHE, Eureka, Cal.

944,188. AIR-GUN. WILLIAM A. HEILPRIN, Philadelphia, Pa.

944,209. BOAT. WILLIAM J. REED, Janesville, Wis.

A boat comprising two tubes spaced apart and filled with compressed air, the ends of the tubes pointed, a keel secured to the underside of each tube and tapered to the pointed ends thereof, a deck secured to the upper sides of the tubes and clearing the plane of said upper sides, a propeller located midway between the tubes at the stern, and a rudder secured midway betewen the tubes near the head end of the boat.

944,213. TIRE-PUMP ATTACHMENT. HARRY H. RUNG, Philadelphia, Pa.

minating in a discharge stem disposed at the longitudinal center of said outlet pipe and extending in the direction of the flow of material therein.

944,301. FLYING-MACHINE. AARON W. H. WARSHAVSKY, New York, N. Y.

944,469. PNEUMATIC-DESPATCH-TUBE APPARATUS. CHARLES F. STODDARD, Boston, Mass.

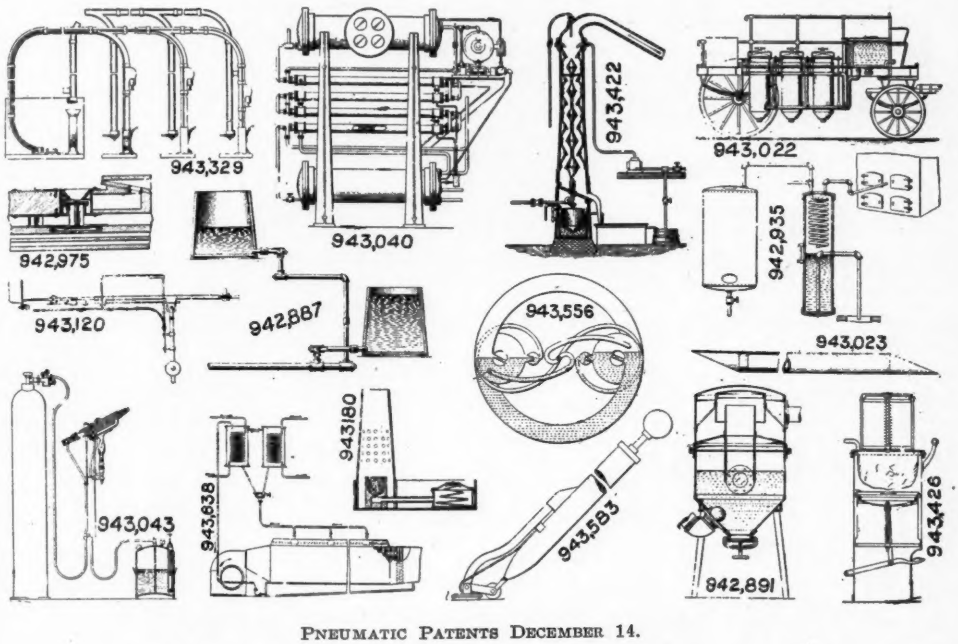
944,473. APPARATUS FOR MAKING OXYGEN. GEORGE VON ACH, Newark, N. J.

944,485. FLUID-PRESSURE BRAKE SYSTEM. JAMES A. HICKS, Atlanta, Ga.

944,487. PNEUMATIC-DESPATCH-TUBE APPARATUS. CHESTER S. JENNINGS, Brookline, Mass.

944,577. HYDROPNEUMATIC SPRING. HENRI OUDINOT and CHARLES PUTOIS, Coudray Montceaux, France.

1. A hydropneumatic spring comprising in combination a cylinder filled with suitable liquid, an air chamber filled with air under pressure inclosed in said cylinder, a piston adapted to penetrate into said cylinder, suitable means for guiding said piston in the bottom of the cylinder, an india-rubber bag co-operating with the head part of said piston, means for guiding said india-rubber bag upon said piston, and means for obtaining a perfect joint between the india-rubber bag, the piston and the cylinder substantially as described and for the purpose set forth.



PNEUMATIC PATENTS DECEMBER 14.

DECEMBER 28.

944,255. PRESSURE-REGULATOR. CLARENCE H. BONG, Chicago, Ill.

944,274. AUTOMATIC GAS-ANALYZING APPARATUS. ERNEST H. PEABODY, New York, N. Y.

944,278. APPARATUS FOR FILLING RUBBER TIRES WITH VISCOUS LIQUIDS. ALBERT D. RAY, Cleveland, Ohio.

3. An apparatus for filling rubber tires, comprising a jacketed charging vessel, an air compression tank and inlet pipe communicating with the upper portion of said vessel, a valved outlet pipe leading from the lower portion of said vessel and terminating in a plurality of tire filling nipples, a plurality of oppositely-disposed oppositely-rotating stirring-blades mounted in said vessel, means for rotating said stirring-blades, an auxiliary charging vessel adapted to be brought into communication with said air inlet pipe independently of said main charging vessel and provided with a valved discharge-pipe ter-

944,672. CHANNELING-MACHINE. ARTHUR H. GIBSON, Easton, Pa.

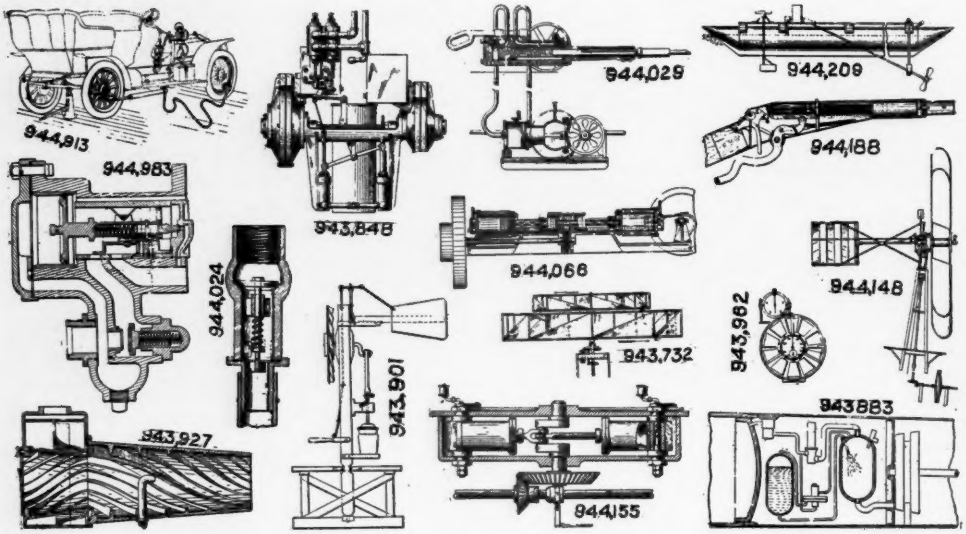
944,717. AGITATING DEVICE FOR MIXING CARBONIC-ACID GAS AND WATER. LOUIS CAUL, Cleveland, Ohio.

944,737. VACUUM MASSAGE-MACHINE. NATHANIEL LOMBARD, Akron, Ohio.

944,750. ROCK-DRILL. WILLIAM C. STEPHENS, Cornwall, England.

944,779. MEANS FOR OBSERVING AND SEPARATING HEAVY OBJECTS FROM DUST-LADEN AIR-CURRENTS. DANIEL FOGARTY, Ottawa, Ontario, Canada.

944,798. PNEUMATIC RELAY FOR AUTOMATIC MUSICAL INSTRUMENTS. ARTHUR W. LONSDALE, Bedford, England.

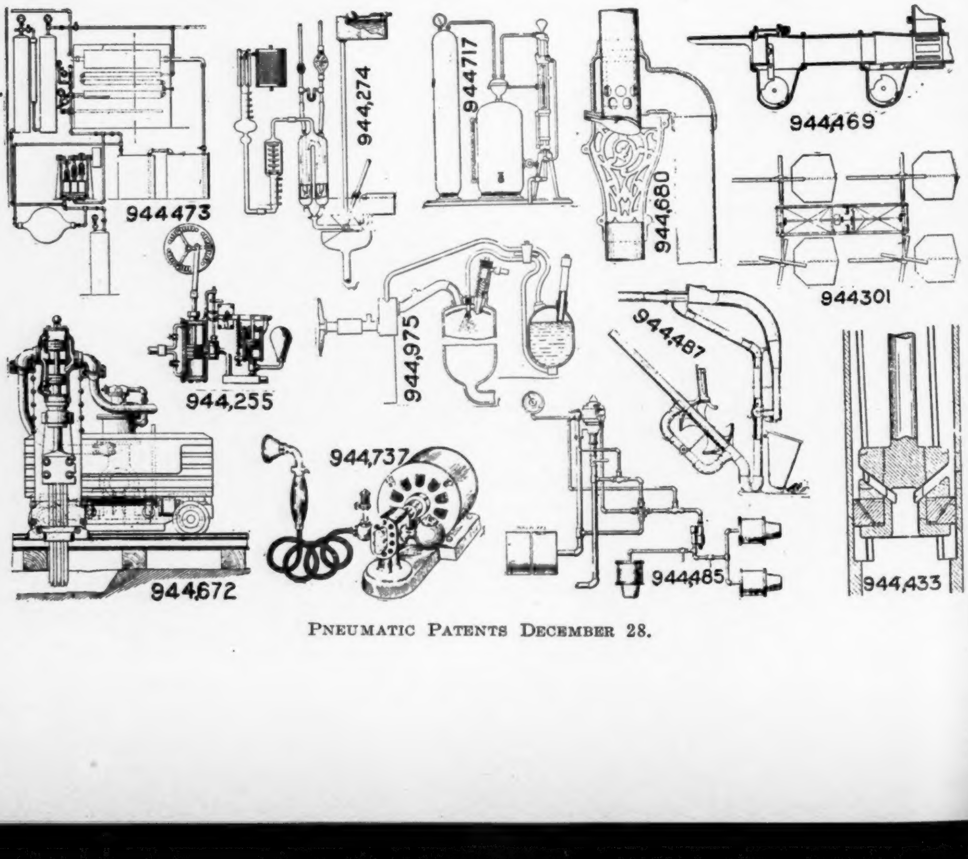


PNEUMATIC PATENTS DECEMBER 21.

944,912. ROTARY AIR AND GAS PUMP. LEBBEUS H. ROGERS, New York, N. Y.

944,975. HEATING OF COMPRESSED AIR FOR USE IN MOTORS. WILLIAM H. SODEAU, Newcastle-upon-Tyne, England.

1. A device for heating compressed air by burning in it a fuel, comprising in combination, a combustion chamber, inlet means for air into said combustion chamber, a deflector situated over the air inlet means and interposed between the fuel inlet means and the air inlet means whereby the main volume of the incoming air is deflected away from the fuel inlet means, said deflector having openings of small area whereby a relatively small quantity of air is passed to support combustion of the fuel issuing from the fuel inlet means.



PNEUMATIC PATENTS DECEMBER 28.

CLASSIFIED BUYERS' GUIDE

Air Cylinder Oil.
- Atlantic Refining Co.
- Borne, Scrymser Co.
- Continental Oil Co.
- **Fiske Bros'. Refining Co.**
- Galigher Machinery Co.
- Standard Oil Co.
- Swan & Co., A. S.
- Vacuum Oil Co.

Air Lift Pumps.
- Curtis & Co., Mfg. Co.
- Galigher Machinery Co.
- Harris Air Pump Co.
- Ingersoll-Rand Co.
- McKiernan Drill Co.
- Westinghouse Traction Brake Co.

Air Gauges.
- Galigher Machinery Co.
- McKiernan Drill Co.
- Westinghouse Traction Brake Co.

Air Receivers.
- American Diamond Sand Blast Co.
- Baldwin Locomotive Works.
- Bury Compressor Co.
- Curtis & Co. Mfg. Co.
- Gardner Compressor Mfg. Co.
- Harris Air Pump Co.
- Ingersoll-Rand Co.
- McKiernan Drill Co.
- Porter Co., H. K.
- Stearns-Roger Mfg. Co.
- Sullivan Machinery Co.
- Westinghouse Traction Brake Co.

Air Tanks.
American Diamond Sand Blast Co.
Baldwin Locomotive Works.
Bury Compressor Co.
Galigher Machinery Co.
Harris Air Pump Co.
Ingersoll-Rand Co.
McKiernan Drill Co.
Porter Co., H. K.
Westinghouse Traction Brake Co.

Aftercoolers, Air.
Bury Compressor Co.
Galigher Machinery Co.
Ingersoll-Rand Co.
McKiernan Drill Co.
Porter Co., H. K.
Stearns-Roger Mfg. Co.
Sullivan Machinery Co.

Belting.
Republic Rubber Co.

Belt Dressings.
Jos. Dixon Cruçible Co.

Blowers.
Cameron Steam Pump Works, A. S.
Galigher Machinery Co.

Blowing Engines.
Cooper Co., C. & G.
Galigher Machinery Co.
Ingersoll-Rand Co.
McKiernan Drill Co.

Brakes, Air.
Westinghouse Traction Brake Co.

Channelers.
Galigher Machinery Co.
Ingersoll-Rand Co.
Stearns-Roger Mfg. Co.
Sullivan Machinery Co.

Charging Stations.
Baldwin Locomotive Works.
Porter Co., H. K.

Coal Cutters.
Galigher Machinery Co.
Ingersoll-Rand Co.
McKiernan Drill Co.
Stearns-Roger Mfg. Co.
Sullivan Machinery Co.

Coal and Ore Elevator Buckets.
Clark Co., W. J.
Galigher Machinery Co.

Compressors, Air and Gas.
Bury Compressor Co.
Curtis & Co. Mfg. Co.
Galigher Machinery Co.
Gardner Compressor Mfg. Co.
Harris Air Pump Co.
Ingersoll-Rand Co.
McKiernan Drill Co.
Powell Co., Wm.
Stearns-Roger Mfg. Co.
Sullivan Machinery Co.
Westinghouse Traction Brake Co.

Compressor Fittings, Air and Gas.
Galigher Machinery Co.
Gardner Compressor Mfg. Co.
Mason Regulator Co.
Powell Co., Wm.
Republic Rubber Co.

Compressor Regulators
Gardner Compressor Mfg. Co.
Mason Regulator Co.

Core Drills, Diamond.
Sullivan Machinery Co.
Core Drills, Diamondless.
Galigher Machinery Co.
Ingersoll-Rand Co.
Stearns-Roger Mfg. Co.
Sullivan Machinery Co.
Corliss Engines.
Cooper Co., C. & G.
Galigher Machinery Co.
Sullivan Machinery Co.
Drilling Machines, Pneumatic.
Galigher Machinery Co.
Ingersoll-Rand Co.
McKiernan Drill Co.
Stearns-Roger Mfg. Co.
Sullivan Machinery Co.
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Ingersoll-Rand Co.
T. H. Proske.
Electro-Pneumatic Machinery.
Galigher Machinery Co.
Ingersoll-Rand Co.
Stearns-Roger Mfg. Co.
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Galigher Machinery Co.
Fans, Ventilating.
Galigher Machinery Co.
Sullivan Machinery Co.
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Curtis & Co. Mfg. Co.
Ingersoll-Rand Co.
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Jos. Dixon Crucible Co.
Graphite Crucibles and Retorts.
Jos. Dixon Crucible Co.
Graphite Greases.
Galigher Machinery Co.
Jos. Dixon Crucible Co.
Graphite Paint.
Galigher Machinery Co.
Jos. Dixon Crucible Co.
Hammer Drills.
Galigher Machinery Co.
Ingersoll-Rand Co.
McKiernan Drill Co.
Stearns-Roger Mfg. Co.
Sullivan Machinery Co.
Hammers, Calking and Chipping.
Galigher Machinery Co.
Ingersoll-Rand Co.
Oldham & Sons Co., Geo.
Stearns-Roger Mfg. Co.

Hammers, Riveting.
Galigher Machinery Co.
Ingersoll-Rand Co.
Oldham & Sons Co., Geo.
Stearns-Roger Mfg. Co.

Helmets, Sand Blast.
C. Druckleib.

Hoisting Machinery.
Galigher Machinery Co.
Lidgerwood Manufacturing Co.
Sullivan Machinery Co.

Hoists, Air.
Curtis & Co. Mfg. Co.
Galigher Machinery Co.
Ingersoll-Rand Co.
McKiernan Drill Co.
Stearns-Roger Mfg. Co.

Hose Couplings and Clamps.
Clark Co., W. J.
Cleveland Pneumatic Tool Co.
Curtis & Co. Mfg. Co.
Galigher Machinery Co.
Harrison Supply Co.
Ingersoll-Rand Co.
McKiernan Drill Co.
Sprague Electric Co.
Sullivan Machinery Co.
Westinghouse Air Brake Co.

Hose, Steam and Air.
American Metal Hose Co.
Curtis & Co. Mfg. Co.
Galigher Machinery Co.
Goodrich Co., The B. F.
Harrison Supply Co.
Ingersoll-Rand Co.

McKiernan Drill Co.
Republic Rubber Co.
Sprague Electric Co.
Stearns-Roger Mfg. Co.
Sullivan Machinery Co.

Locomotives, Compressed Air.
Baldwin Locomotive Works.
Galigher Machinery Co.
Porter Co., H. K.

Lubricating Graphite.
Jos. Dixon Crucible Co.
Galigher Machinery Co.

Lubricating Greases.
Borne, Scrymser Co.
Fiske Bros'. Refining Co.
Galigher Machinery Co.
Swan & Co.. A. S.

Lubricating Oils.
Atlantic Refining Co.
Borne, Scrymser Co.
Continental Oil Co.
Fiske Bros'. Refining Co.
Galigher Machinery Co.
Ingersoll-Rand Co.
Standard Oil Co.
Swan & Co., A. S.
Vacuum Oil Co.

Lubricators.
Powell Co., Wm.

Meters, Air.
Ingersoll-Rand Co.
Metric Metal Works.
St. John, G. C.

Mining Machinery.
Galigher Machinery Co.
Ingersoll-Rand Co.
McKiernan Drill Co.
Stearns-Roger Mfg. Co.
Sullivan Machinery Co.

Motors, Air.
Galigher Machinery Co.
Ingersoll-Rand Co.
Stearns-Roger Mfg. Co.

Nozzles, Air and Sand.
American Diamond Sand Blast Co.
Curtis & Co. Mfg. Co.
Druckleib, C.

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Galigher Machinery Co.
Powell Co., Wm.

Ore Concentrating Machinery.
Galigher Machinery Co.
Stearns-Roger Mfg. Co.

Packings.
Clement Restein Co.

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Galigher Machinery Co.
Ingersoll-Rand Co.
McKiernan Drill Co.

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Galigher Machinery Co.
Jos. Dixon Crucible Co.

Plug Drills.
Cleveland Pneumatic Tool Co.
Galigher Machinery Co.
Ingersoll-Rand Co.
Oldham & Sons Co., Geo.
Stearns-Roger Mfg. Co.
Sullivan Machinery Co.

Pumping Systems, Pneumatic.
Bury Compressor Co.
Curtis & Co. Mfg. Co.
Galigher Machinery Co.
Harris Air Pump Co.
Ingersoll-Rand Co.
McKiernan Drill Co.
Stearns-Roger Mfg. Co.

Pumps, Air.
Cameron Steam Pump Works, A. S.
Galigher Machinery Co.
Harris Air Pump Co.
Ingersoll-Rand Co.
McKiernan Drill Co.
Stearns-Roger Mfg. Co.
Westinghouse Traction Brake Co.

Pumps, Pneumatic Displacement.
Galigher Machinery Co.
Harris Air Pump Co.
Ingersoll-Rand Co.
McKiernan Drill Co.
Stearns-Roger Mfg. Co.
Westinghouse Air Brake Co.

Pumps, Steam.
Cameron Steam Pump Works, A. S.
Galigher Machinery Co.
Stearns-Roger Mfg. Co.
Westinghouse Air Brake Co.

Quarrying Machinery.
Bury Compressor Co.
Blaisdell Machinery Co.
Cameron Steam Pump Works, A. S.
Galigher Machinery Co.
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Sullivan Machinery Co.

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Ingersoll-Rand Co.
McKiernan Drill Co.
Stearns-Roger Mfg. Co.
Sullivan Machinery Co.

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Galigher Machinery Co.
Ingersoll-Rand Co.
Stearns-Roger Mfg. Co.

Sand Blast Machinery.
American Diamond Sand Blast Co.
Curtis & Co. Mfg. Co.
Druckleib, C.
Ingersoll-Rand Co.

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McKiernan Drill Co.
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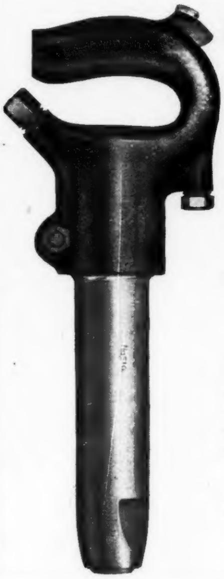

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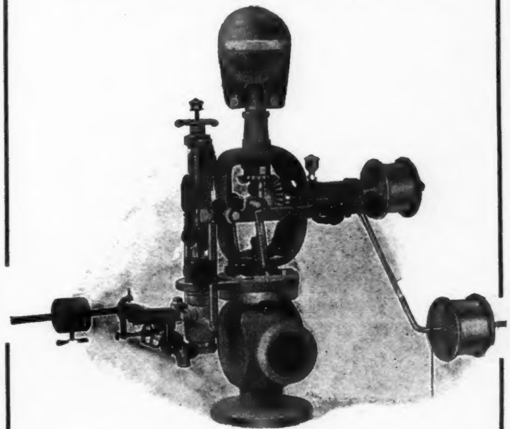

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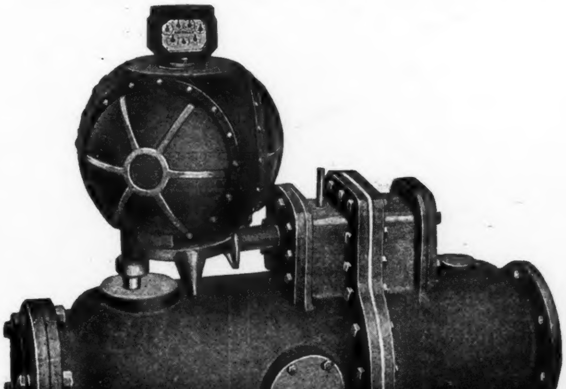

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